TEXTILE RESEARCH JOURNAL

VOLUME XIX June, 1949 *NUMBER 6*

PUBLICATION OF

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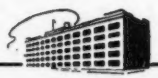

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TEXTILE RESEARCH JOURNAL, published monthly at Prince and Lemon Streets, Lancaster, Pa., is devoted to the interest of research in textile and allied industries. It is the official publication of Textile Research Institute, Inc., and the Textile Foundation.

Manuscripts and communications should be sent to the editorial offices, 10 East 40th Street, New York 16, N. Y.

Subscription rates: General—$15.00 per year; additional for postage, 50 cents to Canada, $1.00 to all other countries. Special—$10.00 per year for United States and Canadian students, teachers, educational institutions, public libraries, governmental libraries and departments, plus 50 cents for postage to Canada. Single copies, $1.50 each.

Entered as second-class matter, April 27, 1945, at the postoffice at Lancaster, Pa., under the Act of August 24, 1912

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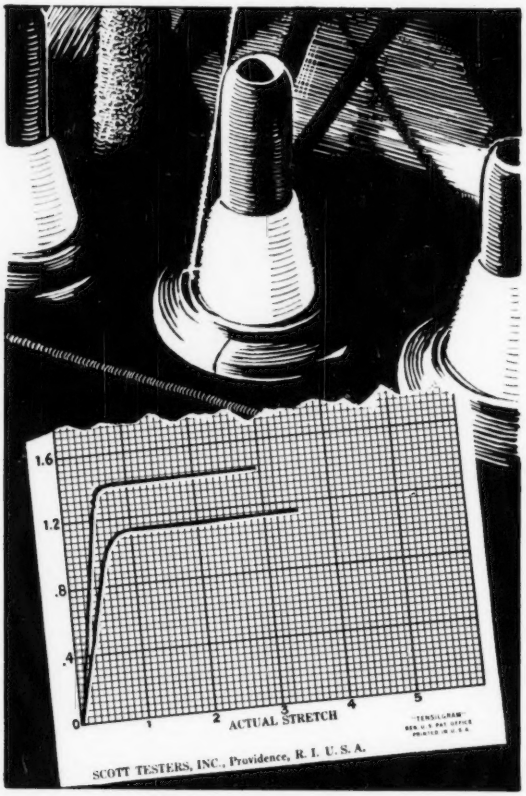

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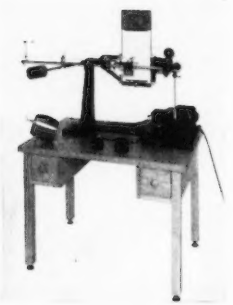

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TEXTILE RESEARCH JOURNAL

VOL. XIX, NO. 6 June, 1949

The Fungi Concerned in Fiber Deterioration

I: Their Occurrence*

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Abstract

A review of the literature and certain new findings are presented which relate to the types of fungi which occur on cellulosic textile fibers under various practical exposure conditions.

Numerous observations, some original and others assembled from the literature, indicate that the following fungi are commonly found growing on fibers in particular types of situations: *Alternaria, Cladosporium herbarum,* and *Fusarium* (especially *F. moniliforme*) on cotton which has undergone weathering in the field before harvest; *Alternaria* and *Cladosporium herbarum* on cotton fabric in relatively short-term moderate- or high-light weather exposures, with *Phoma* and related forms, *Leptosphaeria* and related forms, and *Pullularia pullulans* appearing after longer periods under the same conditions; *Alternaria, Cladosporium herbarum, Pullularia pullulans,* and, under some conditions, *Fusarium* on dew-retting flax and hemp; species of *Aspergillus, Penicillium, Stachybotrys, Chaetomium,* and probably other fungi on cotton and other natural fibers in unprocessed or in textile form in humid storage; *Aspergillus fumigatus* on jute which has undergone microbiological damage in the bale; *Halophiobolus* and certain other unusual salt-water-adapted forms on decaying cordage in marine exposures. Fungi other than the above-named may occur commonly under the conditions mentioned, but if they do this appears not to have been reported frequently or in any detail in the literature. Soil-contact exposures are believed to involve a very wide range of fungus forms, including numerous genera and species which have not been observed to occur commonly in moderate- or high-light above-ground exposures. Information is presented which indicates that resistance on the part of the fungus to sunlight is an important factor in determining which fungi grow on fibers in different types of exposures. Differences among the fungi in moisture requirements and in temperatures favorable for growth are also important.

Introduction

When cotton is not harvested promptly in humid growing regions, it gradually assumes a dull grayish color which generally has been ascribed rather loosely to "weather damage." This color change, which frequently lowers the grade and consequently the market value of the fiber, has been measured by Miss Nickerson [41] and is clearly stated by her to be caused by continued exposure of the fiber in the field before picking, as distinguished from other types of discoloration which are related to other causal factors.

Many persons have believed that weathered cotton has mildew organisms—*i.e.*, fungi—on it but little accurate information has been available on the subject. In studying this problem in our own laboratory it was found that fungi actually are present on such fiber, frequently in abundance, and, in addition, that

* "Part II: Their Ability to Decompose Cellulose" will appear in the July, 1949, issue of TEXTILE RESEARCH JOURNAL.

the principal genera of the organisms involved constitute a very small and characteristic group. It was of interest to us to note from the literature that these same genera had been observed earlier by others on flax and hemp similarly exposed to the weather during the process of dew-retting, and that there were also indications in the literature, subsequently confirmed by our own observations, that at least two of the same genera also occur very commonly on cotton fabrics in short exposures under the same conditions. By contrast, earlier observations by other workers in our laboratory during World War II [60] had shown that the fungus population which appears on cotton fabrics after periods varying from a few to several months' exposure, unshaded, in humid weather is principally characterized by certain entirely different fungus genera. The group of forms which we had observed on cotton and numerous other types of materials in humid storage tests during the war was made up of still different genera, characteristic of this type of exposure.

Information on the above and related topics seemed to be of probable interest to the numerous other workers engaged in various types of fiber deterioration projects in other laboratories. For this reason, even though much remains to be learned about the subject, such information as is now available is summarized here from our own data and from the literature.

Fungi on Cotton Weathered Before Harvesting

It has been observed in our laboratory that certain fungi are found very commonly on cotton which has opened and fluffed normally but has subsequently undergone weathering in the field before harvest. Previous observations of a very limited nature by Prindle [44] had disclosed the presence on such cotton of *Alternaria*, *Cladosporium*, and *Fusarium*. Owen [42] similarly observed *Alternaria* on weathered cotton, although apparently only on a very limited number of specimens. A review of work in Russia by Jaczewski [33] mentions the common occurrence on field-damaged cotton of *Fusarium* spp. and several dark-walled fungi, with *Cladosporium herbarum* as "apparently the most common species found on cotton fibers in the regions investigated." His "*Macrosporium gossypii*" is very closely related to the *Alternaria* of other workers.

Fleming and Thaysen [21] have expressed the belief that actinomycetes are of great importance in the field deterioration of cotton before harvest. They state: "Figure 2 explains the appearance of the large number of short fibers found in deteriorated cottons. They are produced by the action of a streptothrix, a form of microorganism which is always found in large numbers in weathered cottons." As will be noted later, we have not been able to confirm this conclusion. In a second paper [22], the same authors refer to "*Streptothrix chromogena*" on seed cotton. This organism is an actinomycete [35].

In early 1947, observations were made in our laboratory on a series of samples of cotton which had been allowed to remain in the field for approximately 12 weeks during the previous fall before harvesting. It was found that identification of the organisms which had grown on the cotton was much facilitated by placing small tufts of the samples on a thin layer of 2% water agar in petri dishes and allowing incubation for a period of 24–48 hours prior to microscopic observations. The incubation period allows water to be drawn up into the fibers of the tuft and gives the fungi present an opportunity to send out characteristic sporulating structures which render them more easily identifiable. Under these conditions the sporulating structures produced in this relatively short time usually can be clearly seen to be derived from pre-existing fungus growth on the fibers. The microscopic observations usually were made directly on the fiber tufts in place in the petri dishes.

Weathered cotton from many different locations has been examined by the above method. When observations were made on samples collected especially for the purpose from the 1946 crop in North Carolina, Georgia, Louisiana, Texas, and California, three types of fungi were found much more often than any others—namely, *Fusarium* spp. (especially *F. moniliforme*), *Alternaria* sp., and *Cladosporium herbarum*. Yeasts and bacteria were also commonly present. A very brief summary of these observations is given in Table I. The rating in the table is intended only as an approximate index of the amounts of the different fungi present.

As a check on observations on the 1946 samples, further and more extensive examinations were made on similar collections from the crop of 1948. These observations were made primarily on fiber which had remained in the field for approximately 6 and 12 weeks. Fiber of 18 different varieties was obtained at Florence, South Carolina, and of from 2 to 10 varieties from each of eight other locations. Again, as with the 1946 crop, *Alternaria*, *Cladosporium*, and *Fusarium* (especially *F. moniliforme*) were much more common than any of the other fungi found on the fiber. A simplified summary of the observations is included in Table I. Actino-

TABLE 1. SUMMARY OF OBSERVATIONS OF FUNGI ON SAMPLES OF FIELD-WEATHERED COTTON FROM U.S.D.A. COTTON FIELD STATIONS, CROPS OF 1946 AND 1948. A FEW FUNGI OTHER THAN THOSE LISTED WERE PRESENT ON SOME SAMPLES, BUT NEVER IN MORE THAN SMALL OR TRACE AMOUNTS. YEASTS AND BACTERIA WERE PRESENT ON MOST OF THE SAMPLES. ALL OBSERVATIONS WERE ON COTTON WEATHERED APPROXIMATELY 12 WEEKS.

Year	Location	Microorganisms present on fiber		
		Alternaria	*Cladosporium*	*Fusarium*
1946	Shafter, Calif.	++	+++	—
	College Station, Tex.	+	+	++
	Baton Rouge, La.	+	++	+++
	Experiment, Ga.	+	++	++
	Raleigh, N. C.	+	++	—
1948	Shafter, Calif.	+	+++	—
	Sacaton, Ariz.	+	+	—
	State College, N. Mex.	+	trace	—
	Greenville, Tex.	+++	++	trace
	Jackson, Tenn.	++	++	++
	Stoneville, Miss.	++	+++	++
	Auburn, Ala.	+	++	+++
	Florence, S. C.	+++	+++	++
	Statesville, N. C.	++	++	+

mycetes were found frequently but always in small or trace amounts. It is interesting and significant that spore-trapping experiments by investigators interested in allergy indicate that *Alternaria* and *Cladosporium* spores are among the very commonest of the spore types found in the atmosphere [1].

In addition to examinations of weathered seed cotton directly from the field, observations were made by the same method on samples of dark, low-grade, commercial ginned lint from North Carolina, South Carolina, Georgia, Alabama, Tennessee, Arkansas, Oklahoma, Texas, and California. These samples, from the 1947 crop, showed in general a great deal of *Fusarium moniliforme*, with *Alternaria*, *Actinomyces*, *Cladosporium*, and yeasts also present on the fiber from several of the locations.

Several photomicrographs have been taken which illustrate certain typical aspects of the appearance of the more important microorganisms commonly encountered on weathered cotton. A field-exposed fiber from Raleigh, North Carolina, showing a typical hypha or growth filament of *Cladosporium herbarum*, may be seen in Figure 1A. The fungus, it may be noted, is on the outside of the fiber, not in the lumen. Incubation on water agar resulted in the sporulating structures of *Cladosporium herbarum*, to be seen in Figures 1B, 1C, and 1D. The mode of branching is clear from Figure 1B and typical cells at the base of the fruiting branch are shown in Figure 1C. Figure 1D is a photograph taken at a very early stage in the development of the sporulating structure, which is, however, characteristic even at this stage. The spore chains of *Alternaria*, which frequently are found growing out of field-exposed cotton fibers in great profusion after a short incubation period on water agar, are very distinctive in appearance. Figures 2A and 2B show them at two different magnifications. *Fusarium moniliforme* is characterized by a relatively large type of several-septate spores, the macroconidia (Figure 3A), and a smaller type, the microconidia, these latter occurring in both chains and false heads (Figure 3B). An additional characteristic feature of the fungus, as it is seen on water-agar-incubated tufts of weathered raw cotton, is the large number of bridging filaments which it throws across relatively wide air spaces between fibers.

Cotton weathered before harvest frequently is observed to have yeast cells on the fiber (Figure 5B). During incubation on water agar, yeast growth often arises where the fibers are in contact with the agar or as isolated colonies developing from cells which have fallen from the fibers onto the agar surface (Figure 5A). A yeast isolate obtained from cotton weathered at Baton Rouge, Louisiana, was identified for us by Dr. J. Etchells of the University of North Carolina to be *Rhodotorula aurea* or some very closely related species. The same isolate was subsequently identified by Dr. L. J. Wickerham of the U.S.D.A. Northern Regional Research Laboratory as *Rhodotorula aurea*, as were also each of four other isolates, obtained from cotton weathered at Raleigh, North Carolina, Experiment, Georgia, College Station, Texas, and Shafter, California.

A special type of field deterioration of cotton manifests itself in the appearance of unexpanded or unfluffed locks, which are frequently dark in color and may be seen, upon microscopic examination, to have fungus growth on them. In this case, the fungus has grown on the fiber just as the boll opened and before the fiber has had a chance to dry and fluff out. The symptom complex will be referred to here as "tight lock." Tight-lock specimens were examined from several plants grown at Raleigh, North Carolina, in 1946 and from a large number of plants grown at Florence, South Carolina, in 1947 and 1948.

In general, *Alternaria*, *Cladosporium*, and *Fusarium* were the dominant fungi present on the tight locks, although many of the Florence samples had upon them also the fungus *Diplodia*, the dark-walled spores of which are shown in Figure 4. *Diplodia*

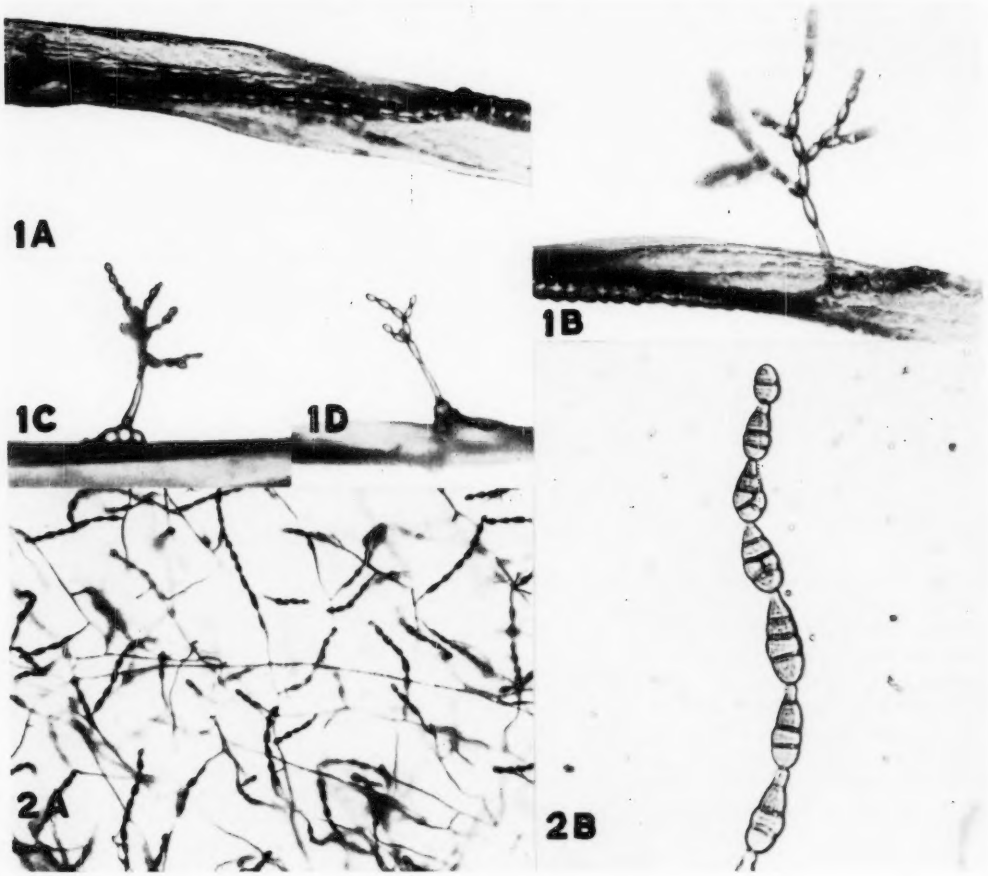

FIG. 1. *Photomicrographs of* Cladosporium herbarum *on cotton fibers weathered in the boll. All approximately 400 ×.* 1A—*Unincubated fiber, showing position of hypha on the outside of the fiber.* 1B—*Characteristic appearance of fungus after incubation of the fiber as described in the text, p. 314.* 1C—*Incubated fiber, showing typical cells at the base of the spore-bearing stalk.* 1D—*Incubated fiber, with very early growth stage of the fungus, showing mode of branching.*

FIG. 2. *Photomicrograph showing typical appearance of* Alternaria, *a fungus very common on cotton weathered in the boll or in textile form.* 2A—*Sporulating growth as seen in view down through colony in petri dish culture. 85 ×.* 2B—*Spore chain under higher magnification. 500 ×.*

is a common cause of boll rot of cotton in the United States, as was shown some years ago by Edgerton [18]. *Glomerella gossypii* was also of common occurrence on these bolls, but apparently usually as a result of insect attack when the fiber was still in the living state. Boll rots resulting from insect puncture are stated by English writers to involve *Rhizopus nigricans* and *Aspergillus niger* [12] or, in some parts of the world, *Ashbya gossypii* [7, 23, 43]. In the U. S. various fungi cause severe lint stain and deterioration following attack by the boll weevil and other insects [15].

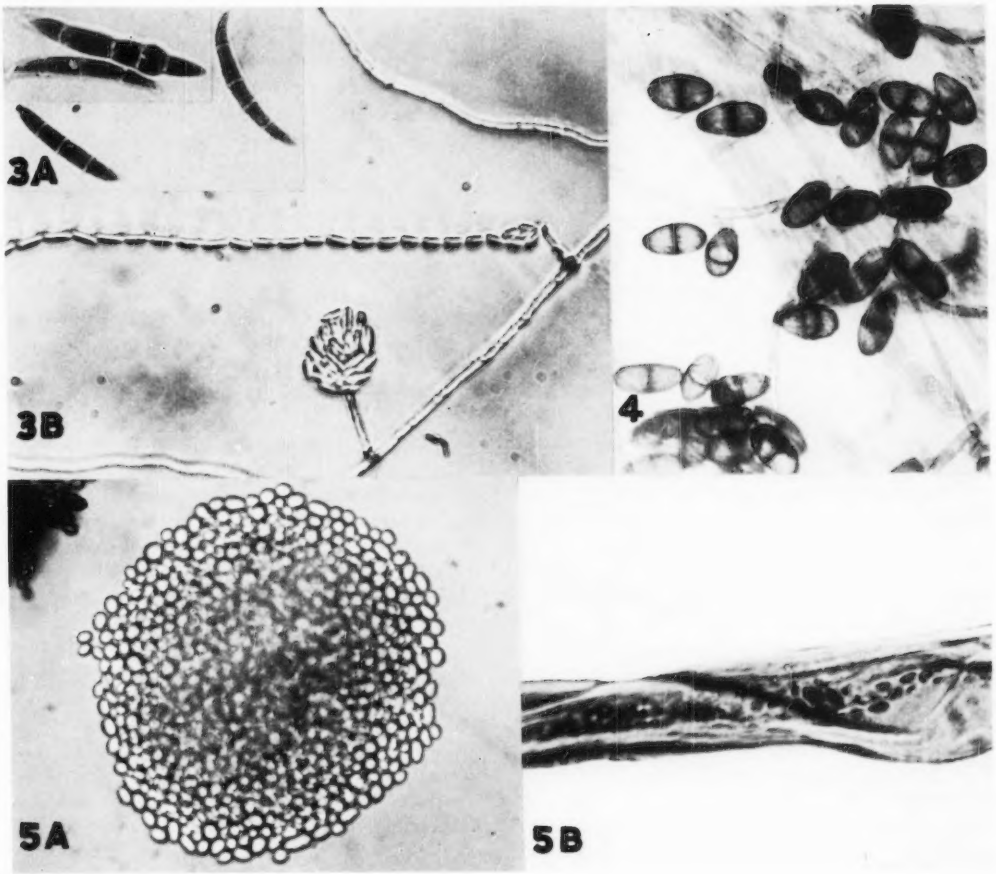

FIG. 3. Fusarium moniliforme, *showing the three spore forms of the fungus, all common on weathered fibers.* 3A—*The macroconidia, stained dark for photographing.* 1000 ×. 3B—*The microconidia, shown in both a chain and a false head.* 370 ×.

FIG. 4. Diplodia *sp., showing spores formed on "tight lock" cotton.* 440 ×.

FIG. 5. *Yeasts, common on cotton fiber weathered in the boll.* 5A—*A young colony on agar.* 370 ×. 5B—*Cells on a field-weathered cotton fiber.* 1025 ×.

Fungi on Cotton Fabrics Weathered Above Ground

Alternaria and *Cladosporium herbarum*, which are so commonly found on cotton exposed to weathering in the field before harvest, frequently occur also in the early stages of weathering of fabric, especially in moderate- to high-light situations. While no extensive examinations of fabrics from such exposures appear to have been made by any single author, *Alternaria* has been observed on them under these circumstances by Guegen [30], Ramsbottom [45],

Broughton-Alcock [13], Neill and Travers [40], Zuck and Diehl [60], Bayley and Weatherburn [10], and workers in India [3]. *Alternaria* was also observed growing on cotton duck exposed to weathering at Beltsville in the summer of 1946 and later in more extensive observations described below. *Cladosporium herbarum* was mentioned as an outstanding important causal agent in the deterioration of tent fabric by both Neill and Travers [40] and Hyde [32]. *Acrothecium*, another dark-walled fungus, has been reported on fabric exposed in India [3] and *Pestalotia*, in Panama [4]. An awning from North Beach, Maryland, examined in our own laboratory exhibited a "shot hole" effect in which we have observed the dark-walled fungus *Coccosporium*.

When cotton plants were left unpicked in order to secure the weathered fiber samples reported in Table I for the 1948 season, 6 in. × 3 in. cloth tags of an 8-ounce gray duck were also tied upon the plants to weather for the same periods in the several locations noted in the table. Observations were made on ravelings from strips taken from six of these locations by the same water-agar technique mentioned earlier in connection with the fiber from the bolls. *Alternaria* and *Cladosporium* were of almost invariable occurrence on the fabric and no other genera seemed to be present in similarly large amounts.

The canvas examined by Zuck and Diehl [60] after several months of unshaded aerial exposure was found to have on it the fruiting bodies of *Leptosphaeria*, *Phoma*, *Diplodia*, and related angiocarpous forms. Figure 6 shows the general appearance of the angiocarps or fruiting bodies of these fungi on the fabric. Neill and Travers [40] also found *Phoma* on the fabric which they examined. The *Coniothyrium* and *Pyrenochaeta*, mentioned along with *Phoma* by White [56 (p. 82)] as genera of frequent occurrence on fabrics, are also of this same angiocarpous fungus type, noted earlier on sun-exposed fabrics by Zuck and Diehl [60]. In addition to the above evidence, angiocarpous fungi have been seen by us in abundance on each of several samples of cotton fabric from sun-exposed sites in Panama.

Pullularia pullulans (Figure 7) was observed by Neill and Travers [40] on cotton fabrics and has been mentioned frequently, both during and since World War II, as a form of common occurrence both on fabrics [4] and on paints exposed out-of-doors. We have found it on an awning collected from North Beach, Maryland, and on a sample of nylon fabric which had been weathered in an unshaded, out-of-door exposure. Presumably, the fungus was growing on some fabric additive in the latter case, since nylon itself is unsuitable as a source of nutrition for fungi. Since the same ability of certain fungi to withstand out-of-door conditions seems to be important in the case of weathered paints as well as weathered textiles, it is of interest to note certain references in the literature to fungi on paints. Goll [29] states: "As far as exterior paints are concerned, *Cylindrocephalum*, *Phoma* (Figure XI), and *Alternaria* were frequently encountered. It should be pointed out that in all these cases *Pullularia* was invariably found and in most instances was the chief agent." Referring to the growth of fungi on paints, Galloway and Burgess [27] mention that "the mould fungi that are most troublesome are dark-colored fungi imperfecti of the *Cladosporium* type." They also mention that "*Pullularia* (Dematium) *pullulans* is not uncommon on oil paints and varnishes." Haenseler [31] reported "*Dematium pullulans*," several species of *Cladosporium*, two species of *Phoma*, and an unidentified fungus causing discoloration of paints.

Pestalotia (Figure 8) has been noted on fabric weathered in Panama [4]. *Curvularia*, another dark-walled fungus (Figure 9), has been found in our own laboratory on numerous samples of sun-exposed fabric from India. *Pestalotia*, *Curvularia*, *Acrothecium*, and *Helminthosporium* are members of a large group of related fungi which are referred to in the literature under a wide variety of names but all have the common character of septate, dark-walled spores. Boedijn [11] has brought out the fact that numerous intergrades between the genera may be shown to exist in this group of the fungi.

Out-of-door exposures involving shade or other causes of low light intensity appear to allow the growth of numerous fungi not common in situations in which the destructive force of sunlight is free to act upon the organisms. *Aspergillus*, *Penicillium*, and *Rhizopus* were stated in an Australian report in 1943 [2] to occur "on the inside, and *to some extent on the outside*, of tents, flies, and tarpaulins" (italics are the present authors'). *Rhizopus*, *Fusarium*, and *Aspergillus niger* were found by workers in India on out-of-doors-weathered cotton fabric, but primarily in the monsoon season when light intensities were unusually low [3]. With respect to the fungus

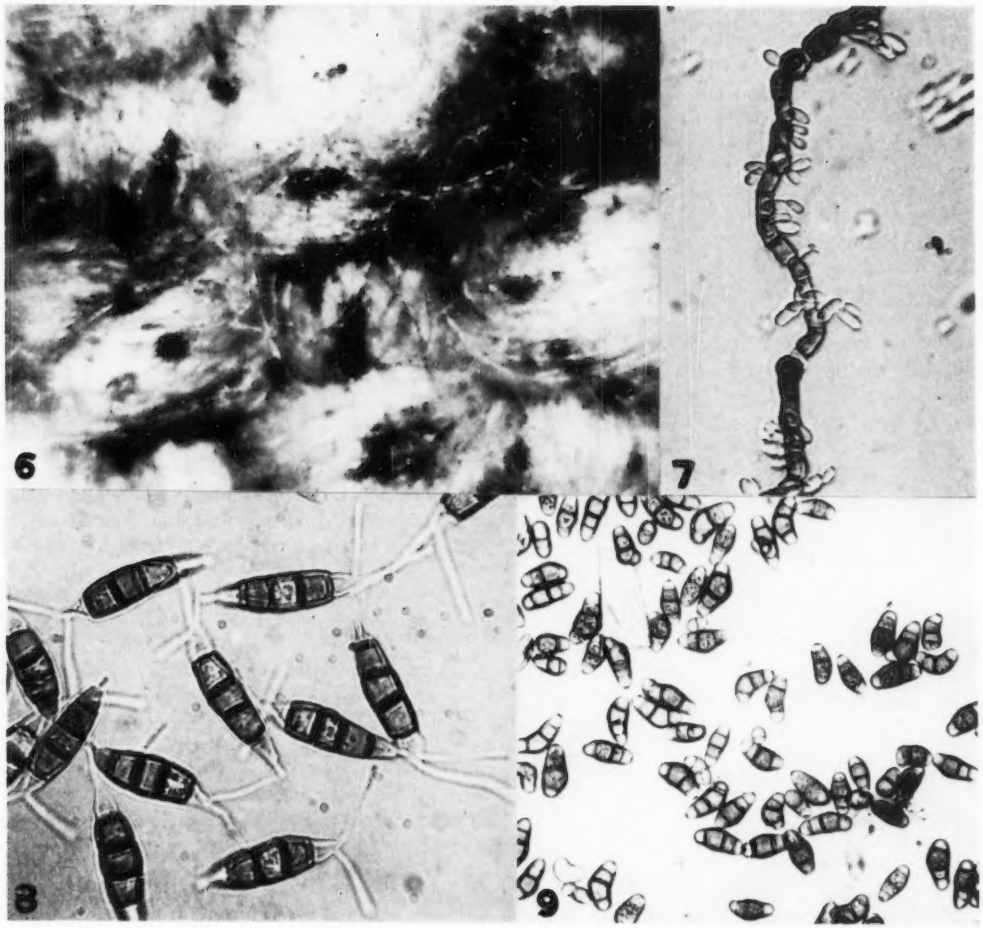

FIG. 6. *Photomicrograph showing appearance of a common type of fungus fruiting body on lower surface of cotton duck after extended weathering in sun-exposed locations. These are the angiocarps of Zuck and Diehl* [60]. *Photo by Zuck.*

FIG. 7. *Hypha and spores of* Pullularia pullulans, *also common on cotton duck after extended weathering in sun-exposed locations. Note spores arising directly by budding from the hypha, a characteristic of this fungus. 440 ×.*

FIG. 8. Pestalotia *sp., noted frequently on cotton fabric weathered in Panama* [4]. *1000 ×.*

FIG. 9. Curvularia *sp., noted especially in the authors' laboratory on cotton fabric samples weathered in India. 370 ×.*

Claudopus variabilis, Zuck [59] states: "The low light intensity and exposure during the rainy season are considered to be of primary importance in the growth and fruiting of this fungus on the cloth." In the case of fabrics exposed to the sun, any fungus growth which occurs takes place very largely on the under or shaded surface of the cloth.

Fungi on Flax and Hemp Weathered During Dew-Retting

Fiber tendering is one of the common difficulties encountered in the retting of flax, hemp, and other fibers. It is interesting to note in this connection that the fungi found to occur on flax and hemp

during the process of dew-retting correspond very closely to those found on out-of-door-exposed specimens of cotton. *Alternaria* has been noted frequently and in large amounts on both flax and hemp [24, 34, 47, 48], as has also *Cladosporium* [24, 34]. *Fusarium* [24], *Phoma* [24], *Cephalosporium* [24], and *Dematium pullulans* (= *Pullularia pullulans*) [34] have also been reported. Jensen [34], commenting upon the fungi which developed on flax in laboratory experiments, states: "*Mucor* sp. and *Cladosporium herbarum* predominated at low (8°–10°C), *Rhizopus nigricans*, *Cl. herbarum* and *Alternaria* spp. at middle (24°–30°C), and *Rhizopus* and *Aspergillus* spp. at high temperatures (37°C). The fungal flora of straw taken from the field was of a somewhat simpler composition, the predominant forms being *Dematium pullulans*, *Cl. herbarum*, and *Alternaria* spp. The absence of *Mucor* and *Rhizopus* seemed at least partly due to inhibitory effect of sunlight."

Fungi on Fibers and Textiles in Humid Storage

Although it is generally recognized as a departure from the best farm practice, cotton is sometimes picked when it is still not entirely dry after a rain or dew and then stored on the farm while still in a moist condition. Similarly it may be exposed to humid conditions during or after its manufacture into a textile, particularly during storage or transit. Damp, indoor exposures result in general in a rather different fungus flora on fibers than has been found to be characteristic of most out-of-door exposures. Armstead and Harland [6] reported in 1923 on the occurrence of an *Aspergillus* of the *A. niger* group and of *Penicillium* spp. on textiles under humid conditions during shipment. Burns [14] in 1927 found species of *Aspergillus*, *Penicillium*, and *Fusarium* on seed cotton after a period of damp storage, while Smith [50] in 1928 reported several *Aspergillus* species as causal agents of mildew of cotton yarns, and in 1929 [51] mentioned also in the same connection the presence of several *Penicillia*, as well as *Alternaria*, *Cladosporium*, and *Stemphylium*. Galloway [26] noted several *Aspergilli* on cotton under humid storage conditions. Prindle [44] in 1934 observed species of *Aspergillus*, *Penicillium*, and *Stachybotrys* on cotton mildewed in humid storage; he specifically distinguished between the fungi found on cotton fresh from the field and those found on samples which had been stored at high humidity. He stated: "They may be divided into two groups: (1) *Penicillium* and *Aspergillus*, characteristic of the stored samples; (2) *Hormodendrum*, *Alternaria*, *Fusarium*, *Sporotrichum*, and Monilia-like organisms, common to the fresh samples." His *Hormodendrum* is now regarded as being completely or almost identical with *Cladosporium* [52]. In view of our obser-

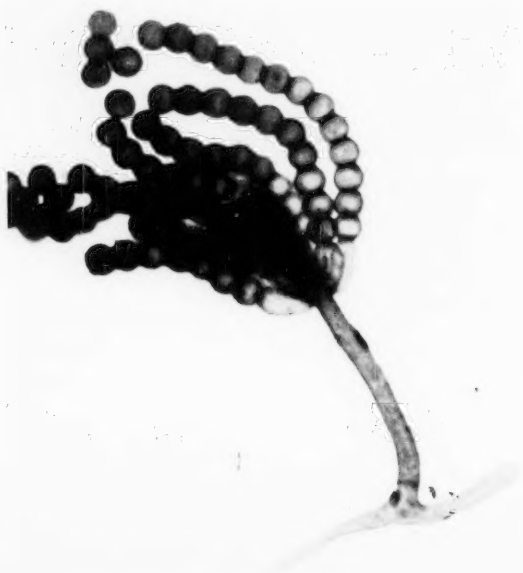

FIG. 10. *Fruiting stalk of* Memnoniella echinata (*1500* ×). *This fungus was reported to be of common occurrence on military articles in tropical areas during World War II.*

FIG. 11. *Perithecium or spore-bearing structure of* Chaetomium globosum *1042.4 (115 ×). This fungus was widely used in textile mildew-resistance tests during World War II.*

vations his "Monilia-like organisms" were presumably *Fusarium moniliforme*. Neill and Travers [40] in 1938 found *Penicillia*, as well as *Rhizopus* and *Mucor*, on cotton in humid storage. If weathered-cotton tufts are prepared for examination by the water-agar incubation method noted earlier but are incubated for 3 or more days instead of the recommended 24–48 hours, they develop growths of *Aspergillus* and *Penicillium* which almost certainly were not growing on the fiber in the field but were merely present as spores which germinated and gave rise to fungus growth during the pre-examination incubation period.

Memnoniella echinata (Figure 10) was mentioned repeatedly during World War II as a fungus of common occurrence on textiles [5]. White [55] has indicated that *Memnoniella* is found predominantly in subtropical and tropical parts of the earth, while the closely related *Stachybotrys* [58] is limited primarily to temperate areas. This is the only case of geographical localization of a non-parasitic fiber-deteriorating fungus known to the authors, such fungi generally being common to both temperate and tropical regions. White [5(pp. 32–4)] has also been impressed with the importance of *Chaetomium* species in tropical fiber deterioration. Although in many cases he does not state definitely whether the specimens on which species of *Chaetomium* were found were from indoor or out-of-door exposures, our own observations suggest that they were probably primarily from humid indoor or shaded storage.* A photograph of *Chaetomium globosum* 1042.4, used very widely in textile mildew-resistance tests in recent years, is presented as Figure 11. White, Siu, and Reese [57] note in their recent paper on the black *Aspergilli* that it is "usually in storage or transit" that these organisms are found on fabrics. Photographs and drawings of *Aspergilli* and *Penicillia* are readily available in the literature [46, 52, 54].

Basu [9] believes *Chaetomium chartarum* to be the most common fungus occurring on jute in damp exposure. According to Smith [52] this species is "frequently mentioned but almost invariably misinterpreted in technical literature," the fungi observed belonging, in fact, to the very closely related genus *Ascotricha*.

Serrano [49] made numerous isolations from abaca fiber which had been damaged by storage in humid warehouses. He mentions species of *Chaetomium*, *Penicillium*, and *Rhizopus* as being of common occurrence, with a note, however, that *Aspergillus flavus*, *Aspergillus fumigatus*, and *Aspergillus niger* were the most prevalent.

Finlow [20] reported *Aspergillus fumigatus* to be exceedingly common in cases of "heart damage" to baled jute. Its occurrence at the high temperatures

* This point has subsequently been verified by Dr. White (personal communication).

which prevail as a result of biological activity inside such bales is not surprising in view of the high temperatures at which this fungus is known to be able to grow [39].

Fungi on Textiles in Soil-Contact Exposures

Although no serious studies known to the authors have been made on the matter, the fungus flora of fabrics in soil-contact exposure is generally assumed to include an extremely wide assortment of genera and species. Numerous papers by authors interested in the agricultural aspects of cellulose decomposition in soils have made it clear that *Aspergillus, Penicillium, Mucor, Rhizopus, Zygorhynchus, Fusarium, Trichoderma,* and many other cellulose-decomposing and non-cellulose-decomposing fungi are of common and widespread occurrence in soils [28]. Several authors have observed that addition of filter paper to soils results in large increases in the number of fungi present as determined by plate counts. In our own laboratory numerous examinations of fabrics have been made incidental to soil-burial testing and a wide variety of different fungi have been observed.

Fungi on Cordage in Marine Exposures

Barghoorn and Linder [8] examined both wood blocks and cordage after marine exposures and described the fungi which they found. Twenty-one new species and 10 new genera were described, the fungi in marine exposures apparently being quite specialized in their ability to grow in the presence of high salt concentrations. The original paper should be consulted for details. It contains the interesting statement that "although the relative significance of bacteria and fungi in the degradation of wood and cordage in sea water has not been quantitatively evaluated, it seems clear to the writer (E. S. Barghoorn) from the evidence presented that marine cellulose-destroying fungi are the more significant organisms, particularly in the early stages of the decomposition process."

General Considerations

It is clear that the fungus population which develops on a fiber sample may contain many kinds of organisms or only a relatively few and that its qualitative composition is much influenced by the type of exposure. The determining factors undoubtedly are related, at least in part, to differences in the ability of the various fungi to grow under, or at least to survive through, longer or shorter periods of (1) moderate or high light intensity, (2) low or very low water supply, or (3) either high or low temperature. The capacity of some fungi for growing with exceptionally small amounts of nitrogen and mineral salts may also be important. Truly anaerobic conditions exclude most fungi, although observations suggest that some may grow better than others in semi-anaerobic circumstances. Since some fungi grow much more slowly than others, the composition of the population may depend also upon the length of the sample's exposure period.

Several workers have shown experimentally that the ability of a fungus to withstand the destructive effects of ultraviolet light is correlated with the occurrence in its walls of dark pigments [16, 17, 19, 25] and that most of the fungi found to occur commonly on fibers in unshaded out-of-door exposures are dark-colored forms with heavily pigmented walls. Such genera as *Alternaria, Stemphylium, Cladosporium, Leptosphaeria, Pullularia, Pestalotia, Curvularia, Coccosporium,* and *Acrothecium* belong in this group. Some of the types described by Zuck and Diehl [60] form special thick-walled structures which undoubtedly contribute to their unusual tolerance toward sunlight. On the other hand, the fungi which are found in indoor or shaded exposures, while they may have dark-walled spores, tend to consist predominantly of forms which have little or no dark coloration in the walls of their hyphae or growth filaments. This group includes species in the genera *Aspergillus, Penicillium, Trichoderma, Rhizopus, Mucor,* and others. Thom and Phillips [53] emphasized the localization in nature of the hyaline or light-walled fungi just below the top surface of the soil, with the darker forms being found in the decaying plant debris on top of the soil. The latter forms, they noted, "predominate only in the presence of air and light." Zuck and Diehl [60] applied the concept of light tolerance in explaining the small number of fungus species observed on sun-exposed cotton duck, while Fuller and Norman [24] and Jensen [34] discussed its importance in determining the fungus population on dew-retting hemp and flax.

The full degree of applicability of mycological information of the type here presented to the solution of fiber-deterioration problems cannot be expected

until it is supplemented by information of other types. It would be useful to know, for example, which of the fungi here described as occurring on fibers are actually able to decompose cellulose and tender cotton and other fibers, and whether the different fungi differ in their sensitivity to protective fungicidal agents. Information on these two subjects is to be presented shortly [37, 38]. Data on other aspects of fiber deterioration are being accumulated in several laboratories; certain parts of this information will undoubtedly be strengthened by and better interpreted through reference to observational data of the type here presented. The reader interested in a general summary of the problem of mildew- and rot-resistance of textiles is referred to an earlier paper in this journal [36].

Acknowledgment

Appreciation is expressed to Dr. H. D. Barker, under whose general supervision the present work was carried out, for helpful advice during the course of the work. The authors wish to express their thanks also to the Messrs. J. B. Dick, J. M. Epps, D. C. Harrell, G. J. Harrison, W. H. Jenkins, A. R. Leding, R. H. Peebles, A. L. Smith, and R. H. Tilley of the several U. S. Dept. of Agriculture cotton field stations for supplying the field collections of cotton for this work, and to Miss Dorothy Nickerson of the U. S. Dept. of Agriculture, Production and Marketing Administration, for providing samples of commercial ginned lint. The photographs were taken by Mr. M. L. Jaeger, and the mounts for the photographs of Figures 6 and 10 were prepared by Dr. R. K. Zuck.

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(*Manuscript received March 4, 1949.*)

Chemical Periodicals in the Dye and Textile Industries

A Statistical Analysis

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AS AN IMPORTANT DIVISION of a comprehensive study being conducted, it was decided to make a statistical analysis of articles appearing in the literature on dye and textile chemistry. A similar study for the field of paint and varnish chemistry has already been published [1].

This study of the chemical periodicals in the field of dye and textile industries was made in order to answer certain questions—What are the important domestic and foreign journals in the field? What is the relative importance of the individual publications? What countries lead in the field? Is Germany holding, or has she lost, her important position? Is it necessary for a research chemist to have a knowledge of a foreign language—and what language? Is there any visible effect of World War II on publications in this field? If a large dyestuff or textile organization decided to subscribe to domestic and foreign journals for its library, which periodicals would seem to be most important?

Collection of Data

It was decided to approach the problem of answering these and other questions by gathering data from the articles abstracted in the Dyes and Textile Section of *Chemical Abstracts* [2], since this publication is now regarded as the most complete abstracts journal in the world. It was considered that a fairly accurate picture could be obtained by taking the data for three complete years. The years selected were: 1947, a postwar year and the most recent for which material was complete at the time of the study; 1942, a war year; and 1937, a late depression and prewar year. The data collected include: number of articles abstracted (no patents); names of contributing journals, with country and language of each publication; and the number of contributing journals. Occasionally, the same article may have been published in more than one journal. After some consideration, it was decided to regard each of these as a separate article. Also, it was decided to tabulate the country of publication rather than the country in which the research was conducted, since many periodicals publish articles from foreign contributors. The "List of Periodicals" [5] was used as a standard.

Tabulation of Data

Five tables have been compiled from the data collected. Table I lists the leading domestic and foreign journals and the number of articles abstracted from them; also, the position of importance of the journal (from the standpoint of quantity of material) in the years considered. Table II contains the corresponding data from the standpoint of country of publication; and Table III, the corresponding data from the standpoint of language of publication. Table IV shows the percentage of all articles published, by country; and Table V, the percentage of all articles, by language.

Interpretation of the Data

From a close study of Table I, it appears that publication in this field has fallen off sharply since 1937, even more so than in the other fields examined to date (paints and varnish, analytical and organic chemistry, and rubber). The number of abstracts published in 1942 is approximately half of the 1937 figure, and in 1947 the figure decreased slightly from 1942. This is very obviously due to World War II, and immediately brings up the question of the status of Germany, at one time generally recognized as a leader in the dyestuffs field and near the front in the field of textiles. Six of the twelve most important periodicals in 1937 were German, holding first, third, fifth, sixth, seventh, and ninth positions. In 1942 there were only two German journals among the

TABLE I. ABSTRACTS BY JOURNAL

Journal	Country	Number of abstracts			Position of journal		
		1947	1942	1937	1947	1942	1937
Textile Research Journal	U. S.	37	4	11	1	—	—
Journal of the Society of Dyers and Colourists	England	35	18	28	2	6	10
American Dyestuff Reporter	U. S.	33	42	87	3	2	2
Society of the Dyers and Colourists Symposium	England	26	0	0	4	—	—
Indian Textile Journal	India	25	11	5	5	13	—
Journal of the Textile Institute	England	23	3	34	6	—	8
Canadian Textile Journal	Canada	16	5	0	7	—	—
Textile Industries*	U. S.	14	*	*	8	*	*
Textile Recorder	England	13	13	9	9	11	—
Textil-Rundschau (new)	Switzerland	13	0	0	10	—	—
Rayon Textile Monthly†	U. S.	12	6	27	11	—	11
Melliand Textilberichte	Germany	11	14	89	12	10	1
Textile Journal of Australia	Australia	11	18	0	13	7	—
Journal of the Chemical Society of Japan	Japan	10	0	2	14	—	—
Textile World	U. S.	9	3	23	15	—	14
Proceedings of the American Association of Textile Chemists and Colorists	U. S.	8	9	1	16	16	—
Teintex	France	8	0	13	17	—	20
Textile Age	U. S.	8	0	0	18	—	—
Textile Bulletin	U. S.	8	18	15	19	8	16
Khimicheskii Referativnyi Zhurnal (discontinued)	Russia	0	50	0	—	1	—
Khlopchatobumazhnaya Promyshlennost	Russia	0	31	0	—	3	—
Textile Colorist and Converter‡	U. S.	7	21	48	—	4	4
Sherstyanoe Delo	Russia	0	20	3	—	5	—
Cotton (Atlanta)*	U. S.	5	16	2	—	9	—
Cotton Research Congress, Proceedings of the Annual Meeting	U. S.	0	12	0	—	12	—
Promyshlennost Lubyanykh Volokon	Russia	0	11	0	—	14	—
Kwagaku to Kogyo (Science & Industry)	Japan	0	10	0	—	15	—
Journal of the Association of Official Agricultural Chemists	U. S.	2	7	0	—	17	—
Klepzig's Textil-Zeitschrift	Germany	0	7	78	—	18	3
Shelk	Russia	0	7	0	—	19	—
Deutsche Wollen-Gewerbe	Germany	0	1	47	—	—	5
Monatschrift für Textil-Industrie	Germany	0	0	44	—	—	6
Deutsche Färber-Zeitung	Germany	0	2	36	—	—	7
Monatshefte für Seide und Kunstseide	Germany	0	0	32	—	—	9
Textile Manufacturer	England	7	3	27	—	—	12
Total Abstracts		510	584	1,065			
Total Journals					123	158	168

* *Cotton* (*Atlanta*), now *Textile Industries*.
† Now *Rayon and Synthetic Textiles*.
‡ Now incorporated in *American Dyestuff Reporter*.

first nineteen (tenth and eighteenth positions), and in 1947 all but *Melliand Textilberichte* (twelfth position) had dropped out of the picture.

Also noticeable is the corresponding decrease in the total number of journals published—168 in 1937, 158 in 1942, and only 123 in 1947. This is probably due to the effects of the war, considering that publication of many journals in countries affected by the war was suspended, notably in Germany. The *Journal of the Chemical Society of Japan* and the Japanese language rate too high in the tables, as the figures taken for 1947 represent a coverage of 6 years, owing to the attempt by *Chemical Abstracts* to cover all information published in Japan during the war years [3].

Consideration of the leading journals of each country, as of 1947, shows that the leading United States journals were TEXTILE RESEARCH JOURNAL and *American Dyestuff Reporter*. The leading English journals were the *Journal of the Society of Dyers and Colourists* and *Journal of the Textile Institute*. The *Indian Textile Journal* and the *Canadian Textile Journal* were among the world's leading publications in this field. The leading German journal

TABLE II. ABSTRACTS BY COUNTRY

Country	Number of abstracts			Position of country		
	1947	1942	1937	1947	1942	1937
United States	189	202	271	1	1	2
England	140	60	154	2	3	3
India	35	16	11	3	7	9
Canada	22	10	7	4	10	11
France	19	13	85	5	8	4
Switzerland	18	11	4	6	9	13
Germany	16	55	408	7	4	1
Australia	15	20	0	8	6	—
Japan (1941–6)	15	23	20	9	5	6
Italy	8	5	12	10	11	8
Belgium	7	0	0	11	—	—
Hungary	5	0	2	12	—	—
Spain	5	0	1	13	—	—
Argentina	4	0	0	14	—	—
Russia	4	154	51	15	2	5
Czechoslovakia	0	0	16	—	—	7
Austria	0	0	8	—	—	10
Finland	0	0	4	—	—	12
All Others	8	15	11	—	—	—
Total	510	584	1,065			

TABLE III. ABSTRACTS BY LANGUAGE

Language of Publication	Number of abstracts			Position of language		
	1947	1942	1937	1947	1942	1937
English	407	318	456	1	1	1
German	34	65	424	2	3	2
French	25	15	86	3	5	3
Japanese	11	17	12	4	4	7
Spanish	10	0	1	5	—	—
Italian	8	5	12	6	6	6
Hungarian	5	0	2	7	—	—
Russian	4	154	46	8	2	4
Dutch	3	2	0	9	—	—
Swedish	1	1	1	10	—	—
Danish	0	3	0	—	—	—
Czechoslovak (Bohemian)	0	0	16	—	—	5
Finnish	0	0	4	—	—	—
Portuguese	0	0	2	—	—	—
Polish	0	0	2	—	—	—
Chinese	0	0	1	—	—	—
Unclassified	2	4	0	—	—	—
	510	584	1,065			

TABLE IV. PERCENTAGE OF TOTAL NUMBER OF ABSTRACTS BY COUNTRY

Country	1947 (%)	1942 (%)	1937 (%)
United States	37.2	34.6	25.4
England	27.4	10.3	14.4
India	6.9	2.7	1.0
Canada	4.3	1.7	0.6
France	3.7	2.2	8.0
Switzerland	3.5	1.9	0.4
Germany	3.1	9.4	38.3
Australia	2.9	3.4	0.0
Japan	2.9	3.9	1.9
Italy	1.6	0.8	1.1
Belgium	1.4	0.0	0.0
Hungary	1.0	0.0	0.2
Spain	1.0	0.0	0.1
Argentina	0.8	0.0	0.0
Russia	0.8	27.4	4.8
All Others	1.5	1.7	3.8
	100.0	100.0	100.0

TABLE V. PERCENTAGE OF TOTAL NUMBER OF ABSTRACTS BY LANGUAGE

Language	1947 (%)	1942 (%)	1937 (%)
English	79.9	54.5	42.8
German	6.7	11.1	39.8
French	4.9	2.5	8.1
Japanese	2.1	2.9	1.1
Spanish	2.0	0.0	0.1
Italian	1.5	0.9	1.1
Hungarian	1.0	0.0	0.2
Russian	0.8	26.4	4.3
Dutch	0.6	0.3	0.0
Swedish	0.2	0.0	0.1
Danish	0.0	0.5	0.0
Czechoslovak (Bohemian)	0.0	0.0	1.5
Finnish	0.0	0.0	0.4
Portuguese	0.0	0.0	0.2
Polish	0.0	0.0	0.2
Chinese	0.0	0.0	0.1
Unclassified	0.3	0.4	0.0
	100.0	100.0	100.0

was *Melliand Textilberichte*, which declined from first position in world importance in 1937 to twelfth in 1947. Journals which have declined in importance from the standpoint of output are: *Khimicheskii Referativnyi Zhurnal* of Russia, which was first in 1942 in number of abstracts but has been discontinued; the German *Klepzig's Textil-Zeitschrift*, third in 1937; and several other German journals that were among the first ten in 1937. The leading French journal was *Teintex*, which was unobtainable during the war. A new journal—the Swiss *Textil-Rundschau*—has made its appearance and gives promise of joining the leading journals in the field.

Examination of Table II reveals that the war had considerable effect on Russian periodicals. There was a large growth between 1937 and 1942, but in 1947 Russian publication in this field had fallen off considerably. The same is true in the field of paints and varnish [1]. According to Crane [4], the 1947 figure for Russia is no doubt low, owing to the difficulty of obtaining Russian periodicals. He further

states that it is fully realized that *Chemical Abstracts* is not covering the more obscure scientific literature of Russia with the same thoroughness that it does that of most other countries.

It must be admitted that the term "important journal" as used in this article has two weaknesses. First, the "importance" is judged by the *number* of articles abstracted rather than by the *quality* of the articles. Second, chemists in this field no doubt feel that a statistical analysis of the abstracts in the *Journal of the Society of Dyers and Colourists* or *American Dyestuff Reporter*, etc., would be a better measure of the "importance" of the various journals. The present study, in which the Dyes and Textiles Section of *Chemical Abstracts* was taken as a rough measure, represents only a part of a more comprehensive study of *Chemical Abstracts* as a whole.

A study of Table II dealing with contributions by country of publication reveals that the United States, second to Germany in 1937, had taken the lead in 1942 and retained it in 1947 by a fair margin over England, which was in second place. Germany dropped to fourth place in 1942 and to seventh in 1947. Two English-speaking countries, India and Canada, moved up to third and fourth positions, respectively, in 1947, from ninth and eleventh in 1937. France dropped to eighth place in 1942 but was fifth in 1947, compared with fourth place in 1937. Italy had dropped slightly in production. Japan showed a decline from fifth in 1942 to ninth place in 1947, but this decline was even greater than appears on the surface, since the 15 articles abstracted in 1947 represent a period of 6 years, owing to the fact that the war-period articles were not available for abstracting until 1947. A sharp decline in publication has been shown by Russia—fifth in 1937, second in 1942, and fifteenth in 1947. Probable reasons have already been given [4], but this situation is nevertheless rather surprising, since Russia is generally considered to have been not that adversely affected by the war. In 1942 the total number of Russian articles abstracted rated second. Several leading Russian journals have been discontinued and the *Journal of Applied Chemistry U.S.S.R.* seems to have been rather slow in absorbing the industrial material. This seems strange in view of Russia's desire to assume a leading position in the fields of pure and applied science. However, the fewer number of journals and the previously mentioned reasons of Crane [4] probably account for the change.

Table IV, which gives percentages of all abstracted articles, by country, shows that in 1947 the United States furnished better than one-third (37.2%) of all articles abstracted, compared with about one quarter (25.4%) in 1937. In 1947 England accounted for about one quarter (27.4%), compared with only 14.4% in 1937. The percentages for all other countries show a sharp decline; all combined make only 35.4% of the total. India, Canada, and Switzerland have shown steady increases in percentage of total abstracts since 1937. Large decreases in percentage for the total number of articles are shown by Germany and Russia. France showed a slight decrease from 1937, but by 1947 had markedly improved her 1942 percentage.

Tables III and V show that the English language was first in importance in each of the three years studied, and that there has been a noted increase in the number of articles in this field published in the English language—79.9% in 1947 compared with 42.8% in 1937. This is due primarily to the fact that the war evidently had less effect on the English-language publications, while many journals in other languages were discontinued or suspended, and partially due to the fact that *Chemical Abstracts* has had some difficulty in procuring some of the more obscure journals, particularly the Russian ones [4]. German-language articles dropped from second place in 1937 to third in 1942 and rose again to second place in 1947, but an examination of the percentages for the total number of articles published in the German language reveals that the percentage has fallen off considerably—from 39.8% in 1937 to only 6.7% in 1947, even though in the latter year it ranked second.

The publication of articles in the French language declined, going from third place in 1937 to fifth in 1942, and then recovered third place in 1947. However, like German, French shows a decline from its 1937 percentage, although the decline is in keeping with the general decline in over-all publication from the 1937 figures.

The number of articles published in the Russian language shows the same effect as that for the number of periodicals from Russia—fourth in 1937 to second (or the leading language next to English) in 1942, but eighth in 1947. The number of Russian-language articles abstracted fell from 154 in 1942 to only 4 in 1947, an abnormal decrease, no doubt due to the reasons previously mentioned. However, Russian will probably again become a leading con-

tender for first place among the languages in this field of publication.

Conclusions

From the standpoint of articles abstracted in the Dyes and Textiles Section of *Chemical Abstracts*, using the number of abstracts as a rough measure of importance of a publication, it was found that in 1947 the most important United States publications in the field were the TEXTILE RESEARCH JOURNAL and the *American Dyestuff Reporter*. The most important English publications were the *Journal of the Society of Dyers and Colourists* and the *Journal of the Textile Institute*. The more important journals in other countries were: the *Indian Textile Journal*, the *Canadian Textile Journal*, the new Swiss *Textil-Rundschau*, *Melliand Textilberichte* of Germany, and *Teintex* of France. The number of articles abstracted is not necessarily a measure of the actual importance or quality of the journal in question but it gives a rough measure of the importance of the journal. Table I shows the relative importance of the journals on the basis of quantity of production.

Table II indicates that in 1947 the countries in which the English language is spoken had a tremendous lead in the number of articles published in the field of dyes and textiles, followed by France, Germany, and Switzerland, in that order.

It would seem from Table III, which shows that almost 80% of the current literature is published in the English language, that knowledge of a foreign language is not essential to the chemist working in these fields, although a knowledge of the German language would be useful in investigating the past literature (almost 40% of all articles abstracted in 1937 were in German, and for previous years the percentages were even higher). Also, in 1942, articles published in the Russian language constituted a little over one quarter of the literature published in the field for that year. However, for the current literature, at least, a knowledge of a foreign language is not essential.

Tables IV and V give the percentages of all articles abstracted, by country and by language, respectively, and indicate beyond any doubt the leading positions of the United States, England, and the English language in the field. United States and English articles have no doubt been more completely covered in this study than those of other countries, but this factor is not great enough to account for the great differences in the number of abstracts.

Examination of the number of articles abstracted and the number of contributing journals shows a decline due, beyond any doubt, to the war and its effects. As a matter of fact, there seems to be some doubt as to the recovery of Germany and the German language to their former position of importance [6].

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(*Manuscript received January 12, 1949.*)

A New Method of Evaluation of the Crystallite Orientation of Cellulose Fibers from X-Ray Data

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IN connection with the study of dichroic reflection of light from textile fibers [8, 9], the writer has conceived the idea of quantitatively verifying the results of optical measurements by x-ray data. The axes of crystallites in a cellulose fiber are oriented at varying angles to the fiber axis. If the number of crystallites oriented in different angular directions can be ascertained from x-ray data, a statistical distribution curve can then be plotted which can be used to check optical measurements.

Sisson and Clark [13] and Sisson [12] were the first to make extensive quantitative studies of the crystallite orientation in cellulose fibers. Their method of evaluation depends upon the assumption that the distribution of crystallites around the pencil of x-rays is proportional to the distribution of intensity around the 002 diffraction ring. This assumption cannot be wholly justified.

Kratky, Hermans, and coworkers, in a number of papers [1, 2, 5], have shown that the orientation factor can be found from the intensity distribution on diatropic interferences. However, since the intensity of the diffraction spot due to the diatropic planes 020 is too weak to be satisfactorily measured, these authors suggested the use of the diffraction spots A_0, A_2, and A_4, due to paratropic planes 101, $10\bar{1}$, and 002 instead; A_2 and A_4, being quite near each other, were measured as a single spot. From these two intensity distribution curves, the average square sine of the angles of orientation, $\overline{\sin^2\alpha}$, and $\overline{\sin^2\alpha}_2$, can be determined. Further, by geometrical considerations, the average value, $\overline{\sin^2\alpha}$, for the diatropic planes 020 can be shown to be equal to the sum of the average values, $\overline{\sin^2\alpha}_0$ and $\overline{\sin^2\alpha}_2$, since the three sets of planes are nearly perpendicular to each other in cellulose crystallites.

That the 101 and $10\bar{1}$ planes happen to be perpendicular to each other is merely a happy accident, and even this is only approximately true. In the case of native fibers, these authors proposed to use the combined spot due to 101 and $10\bar{1}$ planes as A_0 and to derive the A_2-A_4 function from the 002 spot. This relation is again approximate. After all, only the average angle of inclination of the crystallites to the fiber axis is thus obtainable, whereas what is more desirable is the true statistical angular distribution of the crystallites around the fiber axis.

Among the diffraction spots arising from paratropic planes, spot A_0 due to planes 101 is relatively weak. Spot A_2 has the defect of being in superposition with that from planes 021, as pointed out by Hermans [3]. It remains for A_4 to be the most suitable diffraction spot for ascertaining crystallite orientation. By using suitable slit width and time of exposure, it is possible to obtain an x-ray diagram of cellulose fibers with A_2 and A_4 sufficiently separated. The aim of the present work is to devise a method by which it will be possible to analyze the intensity distribution curve of the diffraction spot A_4 to yield a correct orientation curve representing the statistical angular distribution of the crystallites around the fiber axis. The process will be worked out below.

Analysis of Intensity Distribution Curve

In Figure 1 is shown in full line one of the paratropic planes 002 in a crystallite which is oriented at an angle β to the fiber axis. OX, OY, and OZ are a system of rectangular coordinate axes; the fiber axis is supposed to coincide with OY, and Ob, the axis of the crystallite, lies in the plane XY. A pencil of x-rays is incident on this set of planes in the direction ZO at an angle of incidence α. If α is such that Bragg's law $n\lambda = 2d \sin\alpha$ for appearance of a reflection is fulfilled, a spot will appear on the photographic plate in a direction at an angle

β to the equator. Now as a direct consequence of Bragg's law and also as a result of diffraction considerations, it is evident that any other set of 002 planes, shown in Figure 1 in dotted lines, which is parallel to the first but has its axis Ob' making an arbitrary angle γ to the original, will also produce a reflection so the resultant intensity at the point P is the sum of the effects due to all sets of parallel 002 planes having values of γ ranging from 0 to 2π. In other words, the intensity at the point P is due to all crystallites whose 002 planes are inclined to the incident x-ray at an angle α and whose axes are inclined at varying angles θ to the fiber axis, the value of θ being dependent upon the values of α, β, and γ. For $\beta = 0$, θ is equal to γ and may assume all values between 0 and 2π. Hence the intensity at the point P_e in the equatorial direction is actually due to the effects of all crystallites whose 002 planes are inclined at an angle α to the incident x-rays and whose longer axes are oriented in a way the actual distribution of which we are just seeking. To express the problem in another way, we must analyze the intensity of the spot P_e into its individual components in order to obtain a statistical angular distribution curve of the crystallites in the fiber.

To attain this goal, we must first find a relation between the values of θ, γ, β, and α. In Figure 1, unit distance OA is taken along the Y-axis. A perpendicular is dropped from A to the axis of the crystallite Ob, cutting the latter at C. A perpendicular is then drawn through C in the plane (002), cutting some other crystallite axis Ob' at B. Join AB. Simple geometrical considerations show that $\angle ACB$ is complementary to α. In the triangles ACB and AOB, all quantities except the side AB and the angle θ are known. By solving simultaneously, we get the equation

$$\cos\theta = \sin\alpha \sin\beta \sin\gamma + \cos\beta \cos\gamma.* \quad (1)$$

α can be calculated from known values of d and λ, or from the radius of the diffraction spot and the distance from the fiber to the photographic plate. In both cases, α for the 002 planes of cellulose and cellulose hydrate, using $K\alpha$ lines of copper, is very nearly 11°, as will be shown later.

Assigning an arbitrary value to γ successively, say 0°, 10°, 20°, etc., up to 90°, we can calculate sets of values of θ corresponding to varying values of γ. The results so calculated are given in Table I and plotted in Figure 2. The plot is always done for 90° interval of γ, starting from a value of γ corresponding to θ = minimum, which can be easily found by taking the first derivative of θ with respect to γ, setting it equal to zero, and solving for γ. The result is

$$\tan\gamma = \sin\alpha \tan\beta. \quad (2)$$

We can now ascertain more definitely the effects of reflected x-rays from the 002 planes of the various crystallites on the photographic plate. Figure 3 is the fiber diagram and the corresponding intensity distribution curve of the A_1 spot. The intensity at the point P signifies the sum of effects of reflected x-rays from all sets of 002 planes with one definite

* Authorities who reviewed this paper before it was prepared for publication made the following statement: "We feel it would be preferable to reserve the symbol θ for the Bragg reflection angle, as is conventional, rather than to use it to represent some other angle in the diagrams."—*Editor.*

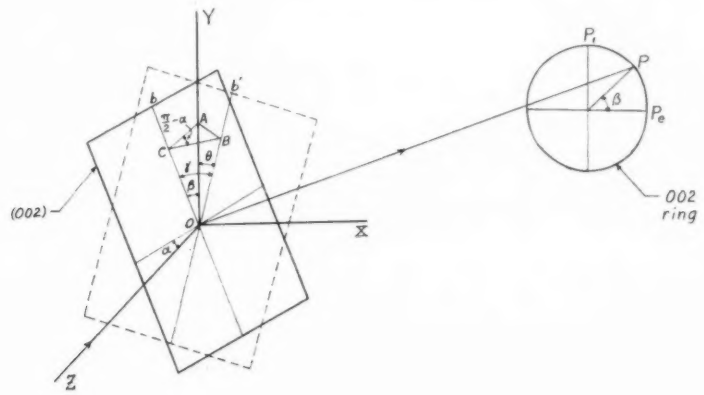


FIG. 1.

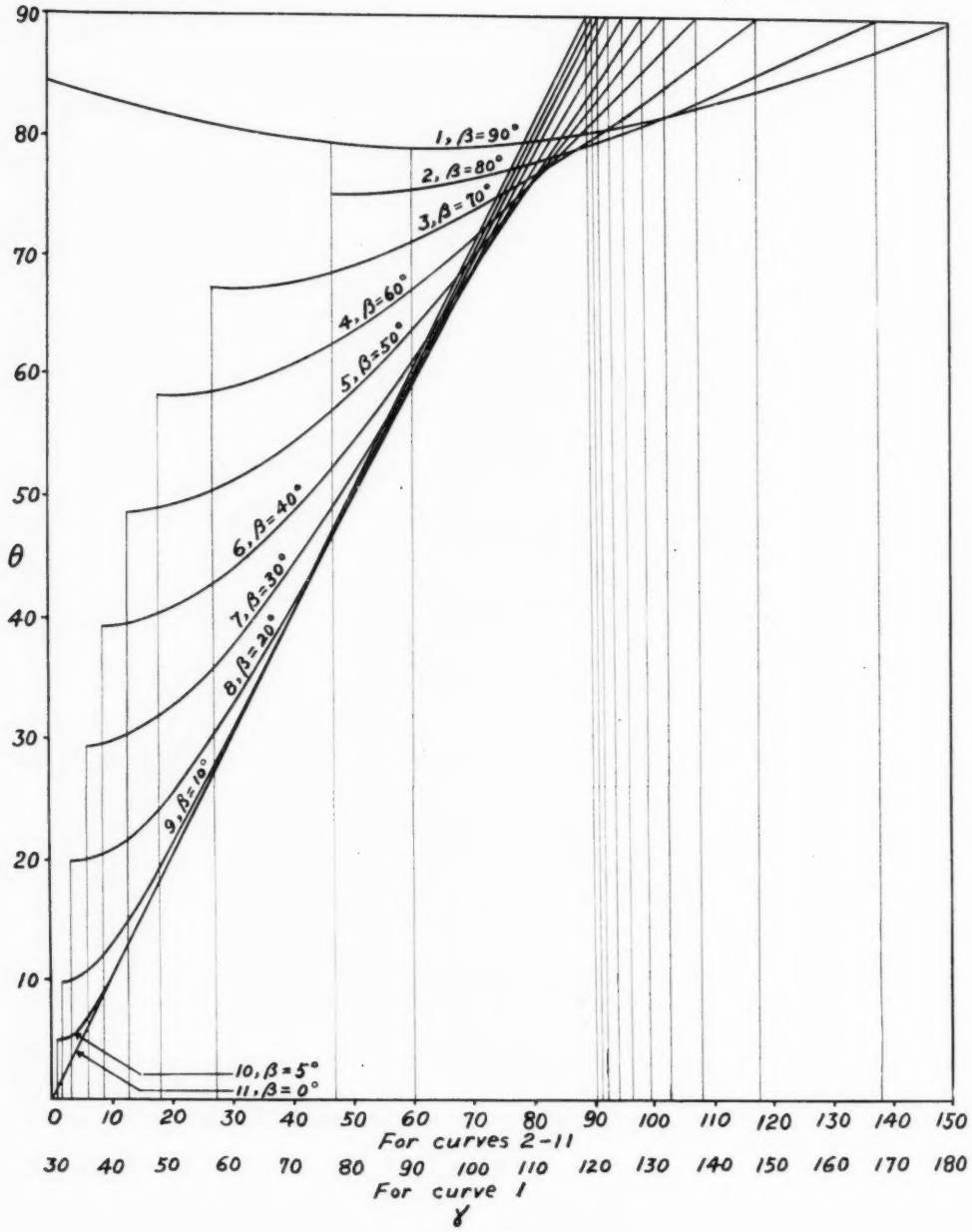

90
80
70
60
50
θ
40
30
20
10
1, β=90°
2, β=80°
3, β=70°
4, β=60°
5, β=50°
6, β=40°
7, β=30°
8, β=20°
9, β=10°
10, β=5°
11, β=0°
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
For curves 2-11
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
For curve 1
γ

FIG. 2.

TABLE I. CORRESPONDING VALUES OF γ INTERVAL AND AVERAGE θ

Average θ	Corresponding values of γ interval									
β = 90	80	70	60	50	40	30	20	10	5	0
83.2	90.0	57.3	36.2	26.8	20.7	17.5	15.9	14.5	13.8	13.9	13.6
76.1		32.7	5.6	1.2	1.2	1.0	0.6	0.6	0.7	0.6	0.6
70.0			48.2	26.3	18.9	15.4	13.3	12.5	11.7	11.5	11.6
60.3				35.7	16.0	11.4	9.7	8.4	7.9	7.8	7.8
51.4					33.2	16.3	12.6	11.2	10.2	10.2	10.0
42.0						28.4	13.2	10.0	9.2	8.8	8.8
32.8							24.7	12.6	10.4	9.9	9.6
22.7								20.2	11.0	10.8	10.6
13.2									15.1	9.0	8.4
6.4										7.5	5.2
1.9											3.8

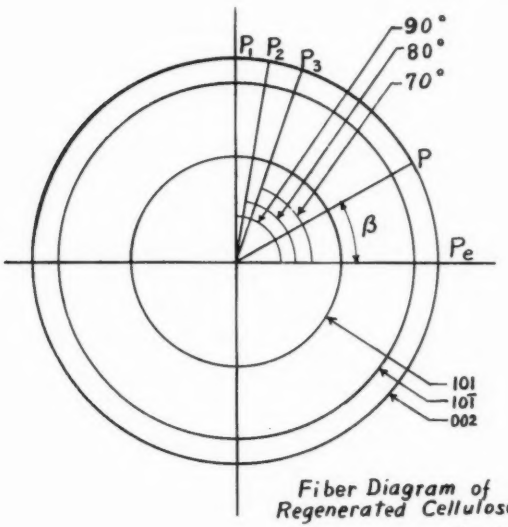
value of β and all possible values of γ (or of corresponding values of θ), these planes all fulfilling Bragg's law of reflection. The intensities at other points on the diffraction spot with other values of θ have similar significance.

By referring to curve 1 of Figure 2 with $\beta = 90°$, it can be seen that when γ changes from 90° to 180°, an interval of 90°, values of θ will vary from 79° to 90°, an interval of 11°. It will be fairly accurate to calculate the average value of θ when γ passes through this change of 90° by finding the area under the curve and between the ordinates $\gamma = 90°$ and $\gamma = 180°$ and dividing this area by the base of the figure; *i.e.*, 90°. The average value of θ so found is 83.2°.

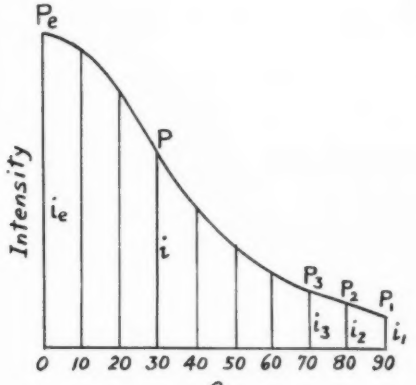
Applying a method of "breakdown" to curve 2 of Figure 2 with $\beta = 80°$, we can find first the interval of γ for which the average value of θ is 83.2°. This is found to be 57.25°. The rest of the interval —*i.e.*, 32.75°—possesses an average θ value of 76.1°.

Extending this method to the rest of the curves 3 to 11 in succession, we can break them into 3, 4, etc., up to 11 parts, each of definite γ interval and average θ value. The results are tabulated in Table I.

To apply the results of "breakdown" to the actual analysis of the intensity distribution curve, we have to assume that orientation is uniaxial; *i.e.*, the number of crystallites included in any definite angular interval is a function of θ only. With this in mind,



Fiber Diagram of Regenerated Cellulose



Intensity Distribution Curve

FIG. 3.

let us start the analysis from the meridional point P_1 (Figure 3) corresponding to $\beta = 90°$. The intensity at P_1 is due to all crystallites with $\beta = 90°$ capable of producing reflection according to Bragg's law and included in the interval $\gamma = 0$ to 2π. Since the conditions in the four quadrants of γ are the same, it is necessary to consider only one quadrant or 90° γ interval, and this simplification will not influence the results of analysis at all. For $\beta = 90°$, the average angle of inclination of the crystallites to the fiber axis is 83.2° and the intensity due to these crystallites is i_1 so that the intensity contributed by 1° interval of γ is $i_1\ 90 = I_1$. In other words, the intensity contributed by crystallites in 1° γ interval in the neighborhood of the direction inclined at an angle of 83.2° to the fiber axis should be I_1.

The intensity i_2 of the point P_2 can be broken down in a similar way into two portions; the first portion of 57.3° γ interval with an average θ value of 83.2°, and a second portion of 32.7° γ interval with an average θ value of 76.1°. The intensity due to crystallites in 1° γ interval of the second portion may be expressed as

$$I_2 = \left(i_2 - \frac{i_1}{90}(57.3)\right) \Big/ 32.7.$$

Similarly, we find I_3 in the neighborhood of $\theta = 70.0°$ to be equal to $I_3 = (i_3 - I_1\ (36.2) - I_2\ (5.6))$ 48.2.

This procedure of analysis can be extended until the entire intensity distribution curve is analyzed into its components. The method will become clearer when an actual numerical example is taken up.

Experimental Procedure

The cellulose samples used for study were ramie, viscose rayons spun with 0% and 30% stretch, respectively, cuprammonium rayon, and Lilienfeld viscose rayon.

The x-rays employed were the $K\alpha$ lines of copper. The distance from the photographic plate to the fiber sample was 5 cm. The time of exposure varied from 6 to 20 hours. Two successive collimating slits, approximately 0.7 mm. in diameter, were used.

Out of two to three photographs taken for each sample, the one with the most suitable density was chosen for intensity measurements. This was done along the diffraction spots around a complete circle; the results of the four quadrants were averaged.

The instrument for making density measurements is a micro-photometer made by the Institute of Physical and Chemical Research, Tokyo. It is a recording instrument, provided also with a visual screen. To avoid the necessity of taking a great number of photographs, the visual method is used. The instrument is provided with a microscope focused on the spot the intensity of which is to be measured. To enable measurements to be made around a circle, a rotating graduated circle is adapted to the microscope stage. In the instrument, the image of the spot is cast upon a slit, behind which a photoelectric cell is placed. The change of potential due to illumination of the image is transmitted to a fiber-electrometer, which is an instrument provided with a very delicate platinum fiber, stretched under slight tension between two charged plates. The variation of potential from the phototube due to change of light intensity from the image is transmitted to the fiber, causing it to experience a small displacement which is magnified by another microscope and cast either upon a photographic plate or upon a visual screen.

The displacement of the fiber of the electrometer was found to be very nearly linear with illumination. To avoid the correction for diffused intensity on the photographic plate, the light from under the microscope was first focused on the lightest portion of the film between the 002 line and the next line of larger diameter for each quadrant [13], and the corresponding readings of the micro-photometer (fiber displacements) were taken. The average of these readings was denoted by I. The light was then focused on a number of points on the diffraction spots the densities of which were to be measured, and the readings I' were taken. The optical density of the point concerned can then be expressed as $\log I/I'$.

For the 101 diffraction spot of regenerated cellulose, intensity readings between the 101 and $10\bar{1}$ spots at 0° and 45° positions in each quadrant were taken and averaged. This is taken as the incident intensity in the calculation of the optical density of the $10\bar{1}$ spot of regenerated cellulose.

Intensity readings just inside the 101 ring at 0° and 45° positions in each quadrant were also taken and averaged. The average of this value and that between the 101 and $10\bar{1}$ rings, as mentioned in the preceding paragraph, was taken as the incident intensity in the calculation of the optical density of the 101 spot of regenerated cellulose.

For ramie, measurements and calculations were done in a similar way except that intensity readings between 002 and $10\bar{1}$ spots and that inside 101 spot were taken and averaged. This was then used as the incident intensity in the calculation of the optical densities of both spots 101 and $10\bar{1}$.

The densities measured were all converted to percentage basis as Sisson and Clark had suggested [13], and these were then plotted against angles to fiber axis accordingly.

Results and Discussions

The relative optical densities (which are proportional to the intensities of x-rays diffracted) vs. angles to fiber axis for the five different samples of cellulose fibers studied are plotted in Figures 4A to 4E. For convenience of reference, these are called intensity distribution curves. X-ray fiber diagrams of these samples are shown in Figures 5A to 5E.

The diameters of the 002 diffraction spot for ramie and for regenerated cellulose rayon are 4.07 and 3.97 cm., respectively, the distance from the fiber sample to the photographic plate being 5 cm. Denoting the angle of incidence of the x-rays for the appearance of a reflection from the 002 planes by α, we have

$$\tan^2 \alpha = 4.07/(2 \times 5) = 0.407,$$

or $\alpha = 11°5'$ for ramie;

$$\tan^2 \alpha = 3.97/(2 \times 5) = 0.397,$$

or $\alpha = 10°50'$ for rayon.

Also, taking the wave length of the $K\alpha$ lines of copper as 1.537 Å and the spacing of the 002 planes of cellulose and cellulose hydrate as 3.92 and 4.03 Å, respectively [6], we can easily calculate the value of α for ramie and for rayon as 11°18′ and 11°0′. Therefore, it will be fairly accurate to take α as 11°0′ in the calculation of γ and θ values given in Table I and plotted in Figure 2.

The intensity distribution curves due to the spot A_1 given in Figures 4A to 4E are analyzed by the method given before. The numerical results of such analysis for the five samples of cellulose fibers are given in Table II. Here i means the intensity contributed by crystallites for different values of β and can be read from the A_1 curves in Figures 4A to 4E. Intensities contributed by crystallites lying in 1° γ interval in the neighborhood of the average θ values given are then calculated and tabulated. These are then plotted against average θ values. The resulting curves are designated as A_1' and are also given in Figure 4. They may be regarded as representing the angular distribution of the crystallites around the fiber axis.

The area under each A_1' curve and between the ordinates 0° and 90° is calculated and given in the same table. The magnitude of this area apparently represents the number of crystallites participating. It is interesting to note that the areas under the curve A_1 are all the same since these curves are already expressed on a percentage basis. After analysis, the areas under the curves A_1' are again different. This is, however, not contradictory to our expectations. It has already been pointed out previously that the object of the analysis is to resolve the intensity of the equatorial point P_1 into its components. Since the intensity i_ϵ of the five A_1 curves

TABLE II. RESULTS OF ANALYSIS OF THE EQUATORIAL INTENSITY OF THE 002 SPOT

		Ramie		Viscose, 0% stretch		Viscose, 30% stretch		Cuprammonium rayon		Lilienfeld viscose rayon	
β	Av. θ	i	I	i	I	i	I	i	I	i	I
90	83.2			3.50	0.0389	2.25	0.0250				
80	76.1			3.50	0.0389	2.39	0.0293				
70	70.0			3.55	0.0397	2.42	0.0280				
60	60.3			3.70	0.0440	2.60	0.0325	0.10	0.0028		
50	51.4			4.00	0.0511	2.94	0.0403	0.70	0.0197		
40	42.0	0.4	0.014	4.46	0.0632	3.63	0.0600	1.80	0.0510	0.60	0.0211
30	32.8	2.2	0.079	5.30	0.0900	4.86	0.0995	4.03	0.1245	2.18	0.0770
20	22.7	5.0	0.191	6.50	0.1311	7.20	0.1925	7.82	0.2718	5.10	0.1940
10	13.2	17.6	0.960	7.90	0.1995	10.20	0.3400	14.10	0.604	17.20	0.933
5	6.4	26.3	1.961	8.49	0.2566	11.80	0.4940	16.90	0.870	25.50	1.875
0	1.9	31.6	2.745	8.88	0.2985	13.45	0.8330	18.00	0.965	30.40	2.590
Area under curve		31.3		9.18		13.27		18.44		31.57	
	i_ϵ	31.6		8.88		13.45		18.00		30.40	

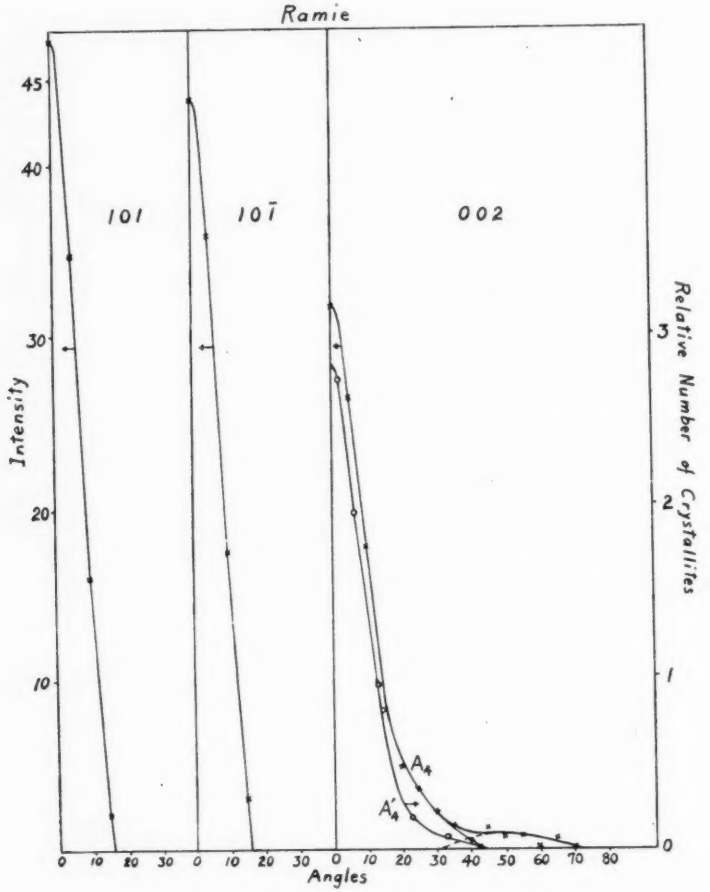


FIG. 4A.

in Figures 4A to 4E is not the same, we shall naturally expect that the number of crystallites which contribute to this intensity will also be different. Furthermore, if this supposition is true, the area under the A_4' curve in Figure 4 should be equal to the corresponding equatorial intensity of the A_4 curve—*i.e.*, intensity i_e corresponding to $\beta = 0$. These values of i_e are actually read from the A_4 curves of Figure 4 and listed in Table II. The agreement comes out to be fairly good.

From the A_4' curves in Figure 4, such quantities as the mean sine or cosine [12] or the percentage orientation [7] can be calculated. For checking the results of dichroic reflection, which will be published elsewhere, the value of average square sines or average square cosines is desired. It must be pointed out here that curves A_4' in Figure 4 do not represent the density distribution of the b axes (normals to diatropic planes) of the crystallites on the pole sphere, but give the relative number of crystallites inclined at different angles to the fiber axis. Therefore, average square sine and cosine should possess the meaning of the equations:

$$\overline{\sin^2\theta} = \frac{\int_0^{\pi/2} f(\theta)\,\sin^2\theta\,d\theta}{\int_0^{\pi/2} f(\theta)\,d\theta};$$
$$\overline{\cos^2\theta} = \frac{\int_0^{\pi/2} f(\theta)\,\cos^2\theta\,d\theta}{\int_0^{\pi/2} f(\theta)\,d\theta}. \qquad (3)$$

Both right-hand members of equation (3) can be found by graphical integration.

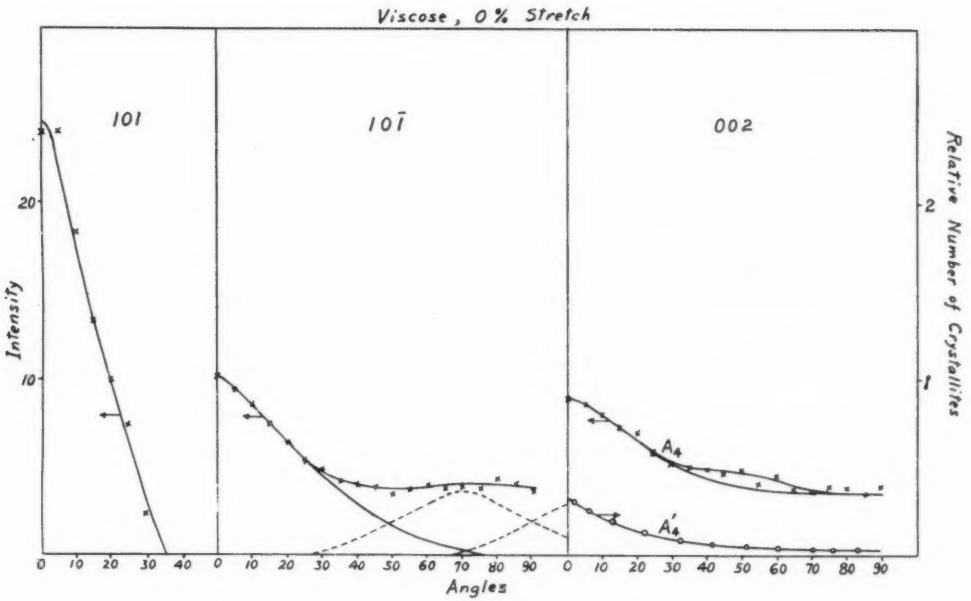

Viscose, 0% Stretch
101
10$\bar{1}$
002
Intensity
Relative Number of Crystallites
Angles
A_4
A'_4

FIG. 4B.

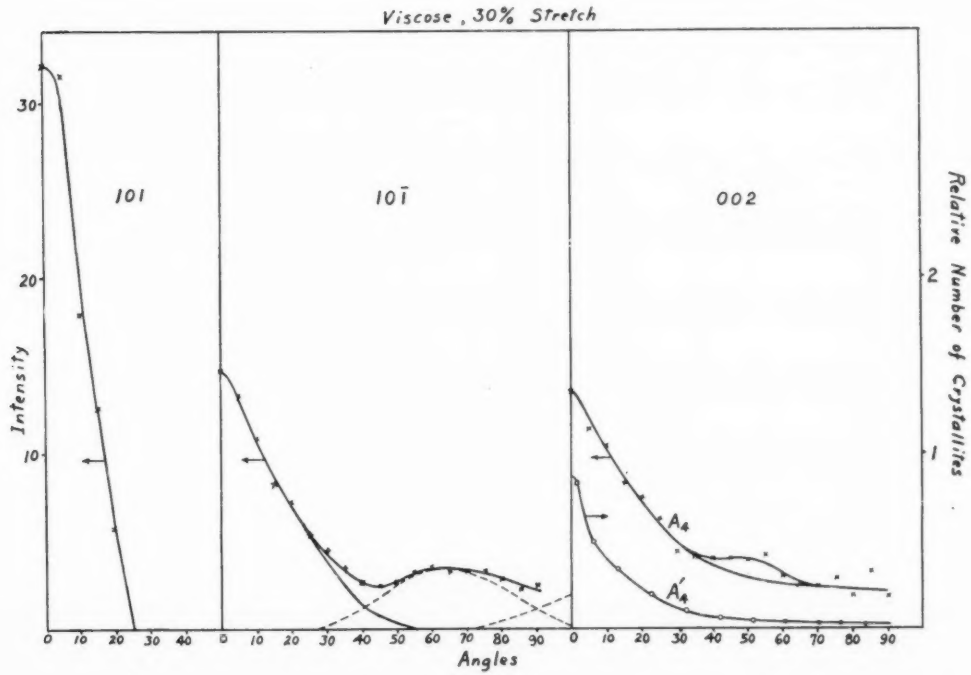

Viscose, 30% Stretch
101
10$\bar{1}$
002
Intensity
Relative Number of Crystallites
Angles
A_4
A'_4

FIG. 4C.

The $\overline{\sin^2\alpha_0}$ and $\overline{\sin^2\alpha_3}$ values are also calculated by the method suggested by Hermans [3, Appendix III]. However, $10\bar{1}$ intensity distribution is used here instead of the combined A_2A_4 function as suggested by Hermans in the case of regenerated cellulose, while for ramie, 101 and $10\bar{1}$ intensity distributions are employed instead of Hermans' combined A_1A_2 and A_4 interferences.

The experimental intensity distribution curves of the $10\bar{1}$ spot in the case of rayons and of the 002 spot in all cases is more or less influenced by the presence of the 021 spot at an angular distance of 60° from the equator. This is especially so in the case of the $10\bar{1}$ spot. For the $10\bar{1}$ and 002 spots of Lilienfeld viscose rayon and cuprammonium rayon, the 002 spot of ramie, and $10\bar{1}$ of viscose rayon spun with 30% stretch, it seems quite certain that the angular spreading of the intensities of the spots will not exceed 60°. Hence it is possible to correct the experimental intensity distribution curve by "mirror-imaging" the tail part of the curve beyond 60° to complete the "correction curve" shown in dotted lines in Figure 4 and then subtracting this "correction curve" from the experimental intensity distribution curve to get the correct intensity distribution curve. In the case of the $10\bar{1}$ spot of viscose rayon spun with 0% stretch, from an inspection of the x-ray photo it would seem that the intensity distribution evidently extends beyond 60°, and hence the correction curve has to be estimated by another method. The maximum of the "correction curve" of the $10\bar{1}$ spot of viscose rayon spun with 30% stretch is multiplied by two factors, one of which is the ratio of time of exposure of the 0%-stretch to the 30%-stretch sample and the other is the ratio of the equatorial intensity of the $10\bar{1}$ curve of the 0%-stretch sample to that of the 30%-stretch sample, to yield the maximum of the "correction curve" for the $10\bar{1}$ spot of the viscose rayon spun with 0% stretch. The correction curve is then further arbitrarily assumed to spread through 90°. The correction so made is of course rather approximate. For the 002 curves, the only correction that can be made is to get rid of the convex portion on the two sides of 60°, which is apparently due to the influence of

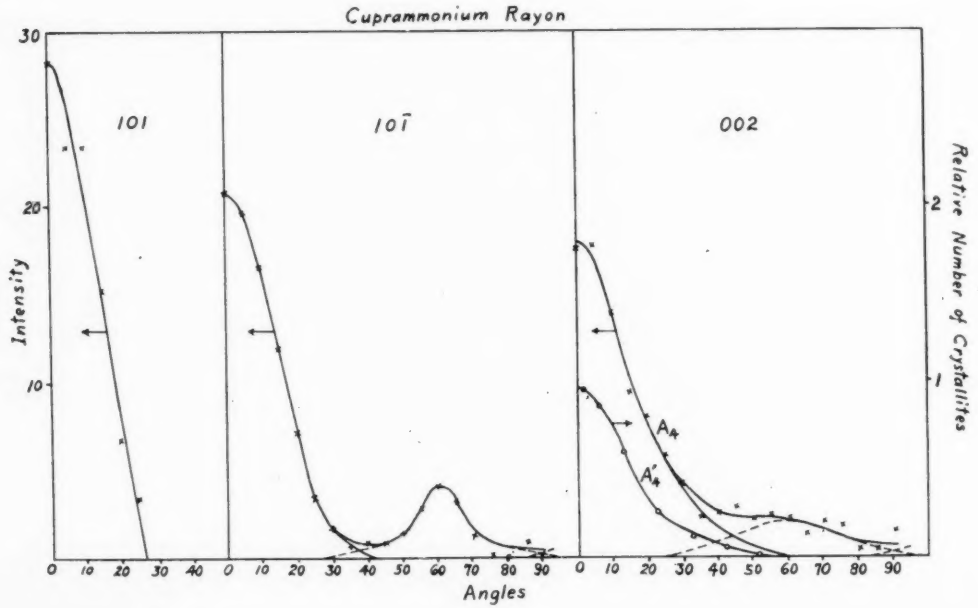


FIG. 4D.

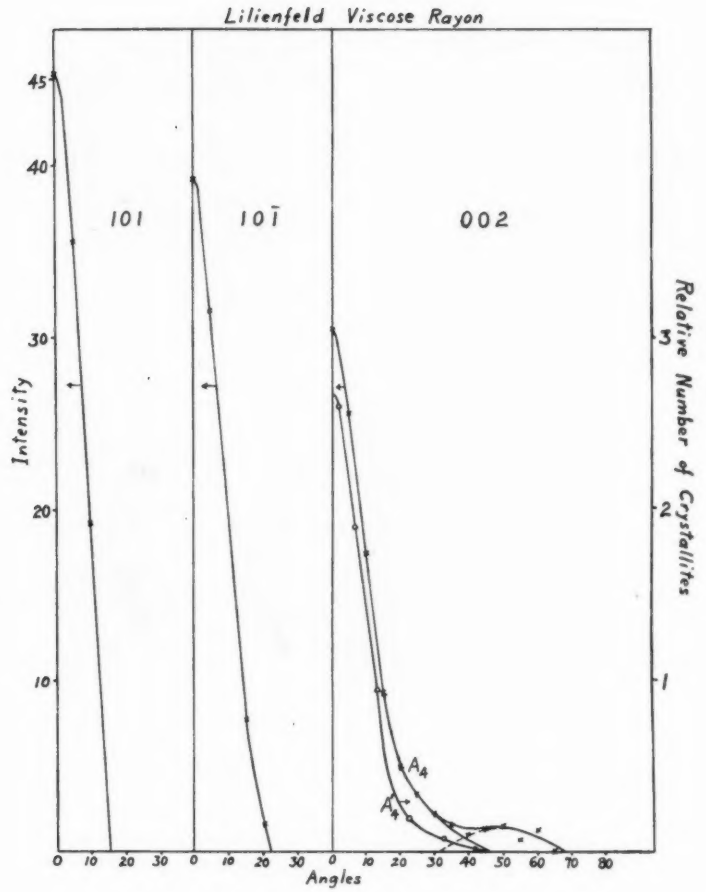


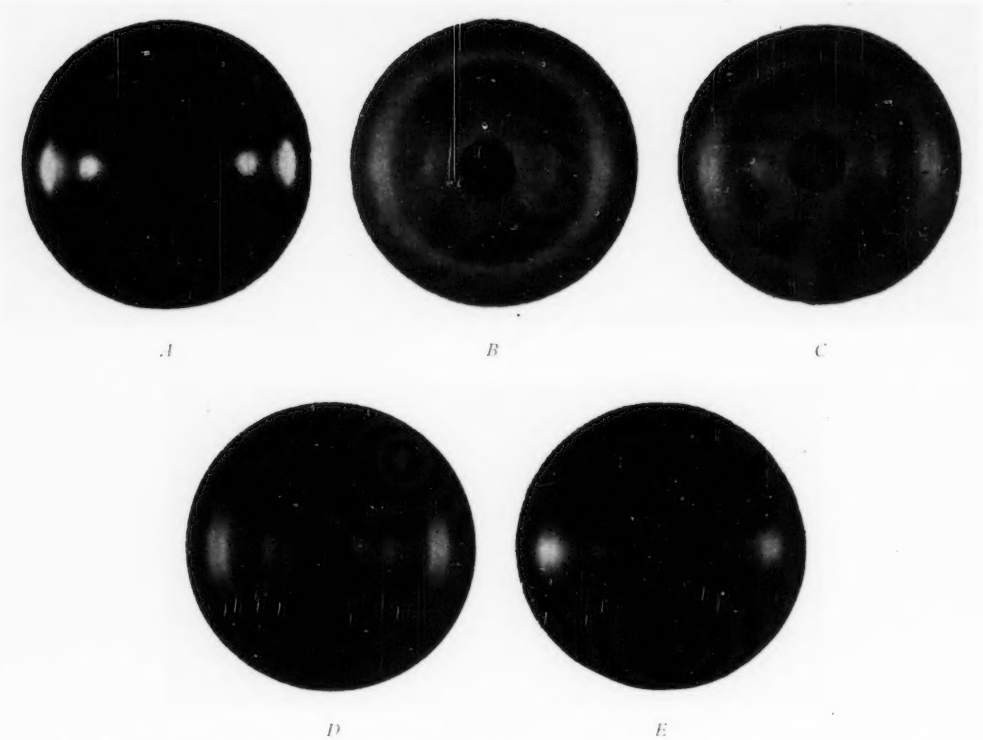
FIG. 4E.

the neighboring 021 spot. The spreading of the 002 spots of the two viscose rayons evidently extends up to 90°, as can be shown by inspection of the x-ray diagrams.

Hermans and coworkers [4] have devised methods for deriving the intensity distribution of the A_3 spot alone from the photometer curves of the superimposed interferences. Unfortunately, the original literature is not available in this part of the world, and hence the details are not known to the writer.

The $\overline{\sin^2\alpha}$ values calculated according to Hermans' method and the $\overline{\sin^2\theta}$ values calculated by equation (3) from angular distribution curves A_4' are all tabulated in Table III. The agreement is moderately good.

It should be noted that the method of analysis as suggested above, strictly speaking, can be applied only to fibers showing uniaxial orientation because of the assumptions we have made at the start. For fibers such as ordinary viscose rayons which show distinctively selective uniaxial orientation [10, 11], the result cannot be expected to be exact. However, as the 002 planes are intermediate between the 101 and 10$\bar{1}$ planes, the $\overline{\sin^2\theta}$ values derived from curve A'_4 may still be expected to be close to the actual average inclination of the crystallites to the fiber axis.



A *B* *C*

D *E*

FIG. 5. *A—Ramie. B—Viscose, 0% stretch. C—Viscose, 30% stretch. D—Cuprammonium rayon. E—Lilienfeld viscose rayon.*

Summary

Based upon the assumption that the number of crystallites included in any definite angular interval is a function of the angle to the fiber axis, a method is devised by which the equatorial intensity of the 002 diffraction spot can be analyzed into its components to give the angular distribution curve of crystallites around the fiber axis. Values of average sine are calculated and these can be checked by average square sine values calculated from the other two nearly perpendicular paratropic planes. Moderate agreement is obtained.

Acknowledgment

The x-ray photos presented in this paper were taken in the Physical Laboratory of the University of Manchester, and for the use of them the writer is much indebted to the University Authority. Thanks are due to Dr. S. H. Yu, now of National Tsing Hwa University, for his kind help during the preparation of x-ray photos, and to Dr. H. C. Wu, Director of the National Research Institute of Chemistry, Academia Sinica, for permission to use

TABLE III. AVERAGE SQUARE SINE VALUES OF RAMIE AND RAYONS

	$\sin^2 \alpha_0$	$\sin^2 \alpha_3$	$\sin^2 \alpha$	$\sin^2 \theta$ (from A_1')
Ramie	0.012	0.013	0.025	0.035
Lilienfeld viscose rayon	0.013	0.018	0.031	0.037
Cuprammonium rayon	0.036	0.049	0.085	0.082
Viscose rayon, 30% stretch	0.028	0.088	0.116	0.154
Viscose rayon, 0% stretch	0.055	0.142	0.197	0.252

the micro-photometer. Lastly, but not the least, the writer wishes to thank Dr. R. Z. Yung, the Director of this Institute, for his constant encouragement and generous patronage.

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(*Manuscript received December 13, 1948.*)

Mathematical derivation of equation (1) and also some additional experimental data were received too late for publication in this article. This material will appear in the July, 1949, issue of TEXTILE RESEARCH JOURNAL.—*Editor.*

INDUSTRIAL SECTION

Temperature Measurements of Moving Textile Material

C. W. Bowden, Jr.*

A TEMPERATURE MEASURING METHOD which does not require physical contact between the goods and the detecting element has recently been developed. It consists of measuring the heat radiation from the surface of the fabric. This method has been used for some time in high-temperature pyrometry, but has only recently been adapted to the temperature range encountered in the textile industry.

The need for measuring the temperature of moving fabrics is becoming more and more apparent. As drier temperatures are raised to increase drying efficiency, the danger of tendering goods by excessive heating becomes more real. Furthermore, the use of curing-type resins for special finishes requires that the goods be exposed to a definite temperature for a certain period of time. Unless this temperature is reached, the cure is incomplete. There are various other applications in the industry which are equally important.

Measurement of the temperature of moving fabrics by conventional means is not a simple matter. Even when the fabric is not moving, it is difficult to press a contact-type temperature-sensing element, such as a thermocouple or thermometer bulb, firmly enough against the surface of the piece of cloth to obtain its true temperature. This is caused not only by the characteristics of the surface but also by the lack of stiffness of the fabric which prevents the use of pressure to improve the contact.

Another property of cloth which complicates accurate temperature measurement is its relatively poor heat conductance, together with the small mass in contact with the sensing element. If the temperature-measuring element has appreciable mass, it will conduct heat away from the fabric which it touches faster than heat can migrate to the contact point from the surrounding textile material. Erroneous readings result.

When the cloth is moving, an additional complication arises—namely, the frictional heat generated between the fabric and the sensing element. This heat is variable, depending upon the condition of the cloth, the surface of the cloth, its speed of movement, and the type of temperature-sensing element employed. Consequently, it is not practical to compensate for this effect by a correction factor.

Because of the difficulties mentioned, as well as some others which are more complex, measurement of the temperature of moving fabrics by conventional means is not considered feasible. So far as is known, it has never been satisfactorily accomplished by contact methods.

Radiation Pyrometry

In order to appreciate the operation of a radiation pyrometer, some discussion of radiant energy is necessary. It is well known that all objects which are warmer than absolute zero (-459° F) radiate heat energy. Conversely, all objects are capable of absorbing radiant energy from other bodies at higher temperatures.

The quantity of energy which is radiated from a body is dependent upon its temperature, its composition, and also upon the condition of its surface. In general, the more reflectance shown by a body, the lower will be the quantity of energy emitted. Thus, an object with minimum reflectance will emit the greatest quantity of energy. Such an object is known as a *blackbody* and is said to have an *emissivity* of unity. Most common materials are not blackbodies and show emissivities of less than unity.

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"Emissivity" may be defined as the ratio of radiant energy emitted by a body to that which is emitted by a blackbody at the same temperature.

The radiant energy emitted at the relatively low temperatures encountered in the textile industry is quite different from that emitted at high temperatures, including the visible spectrum. Figure 1 shows the wave-length distribution of energy at various lower temperature levels. It will be noted that the radiant energy at these temperatures is entirely outside the visible range. Personal experience confirms this fact, of course, since radiation at such temperatures is invisible.

Confirming the difference between high- and low-temperature radiant energy, it is interesting to observe that Pyrex glass, which is transparent and reflectant to visible light and high-temperature radiation (and consequently has a very low emissivity), becomes opaque and a nearly perfect blackbody to low-temperature radiation. This is shown in Figure 1 by the fact that the cut-off point for Pyrex is less than 3 microns, while practically no part of the radiation of the temperatures plotted has a wave length of less than 3 microns.

Transparent films of cellulose derivatives are somewhat similar to glass in their opacity to low-temperature radiation. Figure 2 shows that a clear lacquer is far less transparent to low-temperature radiant energy than it is to visible light. In fact, the emissivity of this material is rather high, as shown by the fact that two thin coats of the lacquer on bright copper raises the emissivity from less than 0.1 to approximately 0.6.

At low temperatures, blackbody conditions, or a close approach to them, do not necessarily require blackness. Figure 3 shows the emissivities of several paints or refractory materials. It will be noted that black paint actually has a lower emissivity than other colors in the 200° to 400°F temperature range. The visible color of a surface consequently is obviously not an indication of its relative emissivity at these low temperatures.

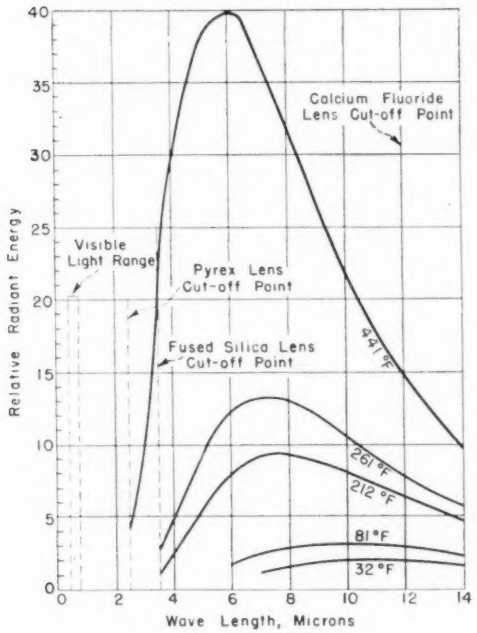

FIG. 1. *Curves showing relative radiant energy versus wave length for a blackbody at relatively low temperatures.*

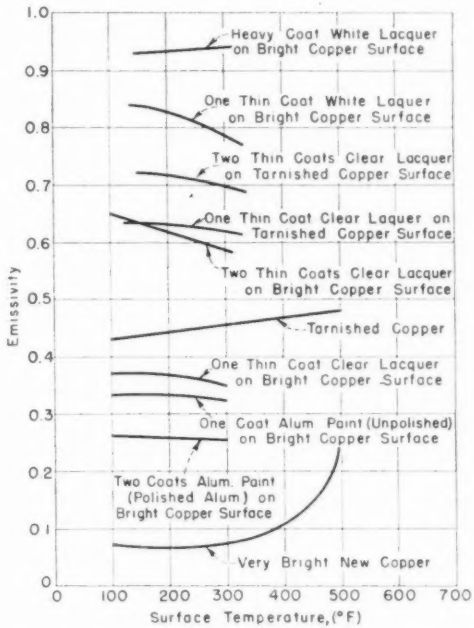
Emissivity
Surface Temperature,(°F)
Heavy Coat White Lacquer on Bright Copper Surface
One Thin Coat White Lacquer on Bright Copper Surface
Two Thin Coats Clear Lacquer on Tarnished Copper Surface
One Thin Coat Clear Lacquer on Tarnished Copper Surface
Two Thin Coats Clear Lacquer on Bright Copper Surface
Tarnished Copper
One Thin Coat Clear Lacquer on Bright Copper Surface
One Coat Alum. Paint (Unpolished) on Bright Copper Surface
Two Coats Alum. Paint (Polished Alum.) on Bright Copper Surface
Very Bright New Copper

FIG. 2. *Emissivities of copper, uncoated, coated, and tarnished, versus temperature.*

Radiation Characteristics of Textile Fibers

Some data have been collected on the emissivity of sized cotton yarn while it was passing over a stainless steel cylinder. The sets tested were 2,300 ends of cotton 9's at 260°F, 4,500 ends of cotton 30's, and 5,000 ends of cotton 45's, the latter two both at 250°F. The tests were made by sighting the radiation pyrometer first at a stripe of dull black paint on the cylinder and then at the sheet of warp yarn. In all instances the recorded temperature dropped less than 5 degrees as the unit was changed from sighting on black paint to cotton yarn. The color of the yarn made no apparent difference in the reading. Furthermore, as was expected, the results were the same whether the yarn was moving or stationary. Since it is known that the emissivity of black paint is high (see Figure 3), the inference is that the emissivity of cotton yarn is also high.

The limited data now available therefore indicate that radiation pyrometry is well suited to temperature measurement of cotton textile materials. Whether or not radiation pyrometry will be useful with other types of fibers and with the various fabric constructions is still conjectural, but currently available data on other organic substances give promise of widespread adaptability of this method in the textile industry.

Effect of Humidity

There are a number of water-vapor absorption bands within the 1- to 12-micron wave-length range involved in low-temperature radiation pyrometry. The loss of radiant energy due to humidity in the atmosphere of the pyrometer sighting path, therefore, must not be overlooked as a factor in consistent measurement. Furthermore, the greater the distance between the object and the pyrometer, the greater this loss, because the radiation has to pass through more water vapor.

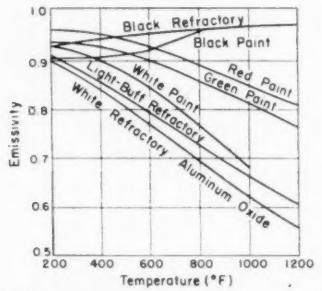

FIG. 3. *Emissivities of several paints and refractories versus temperature.*

In the majority of applications, the ambient humidity is relatively constant and the moisture present merely reduces the energy incident upon the pyrometer somewhat but does not interfere with the reproducibility of readings. It is estimated that in the normal ambient temperature zone of 75° to 80°F a change in the relative humidity from 40 to 50 percent (or from 40 to 30 percent) will result in an energy change of less than 1 percent under normal operating conditions.

The Low Range Radiamatic

The only radiation pyrometer currently available for measuring relatively low temperatures is the new Brown Low Range Radiamatic. It will produce satisfactory results when the following six conditions are met:

1. Work temperatures lie between 100° and 600°F.
2. Emissivity of the surface sighted upon is reasonably high and remains relatively constant.
3. The temperature around the sensing unit is below 120°F and is not subject to sudden extreme variations.
4. The target area sighted upon is ample in accordance with the values given in Table I.
5. The pyrometer "sees" the work only—that is, reflected radiation is eliminated by shielding if necessary.
6. Excessive dust or smoke is kept out of the pyrometer line of sight. (Where dust or smoke is present in the line of sight, it can sometimes be eliminated by air purging.)

Even where all of these conditions are not met, it is possible in some cases to use the pyrometer. For example, some users are measuring temperatures as low as 32°F.

TABLE I. REQUIRED TARGET FOR LOW-RANGE RADIATION PYROMETER INSTALLATIONS

Distance between lens and target (ft.)	Minimum target diameter at right angle to line of sight (in.)
$\frac{1}{2}$	$2\frac{3}{16}$
1	$3\frac{1}{2}$
$1\frac{1}{2}$	$4\frac{7}{8}$
2	$6\frac{3}{16}$
3	$8\frac{7}{8}$

NOTE: Where the target distance is greater than 3 feet, special engineering consideration is required.

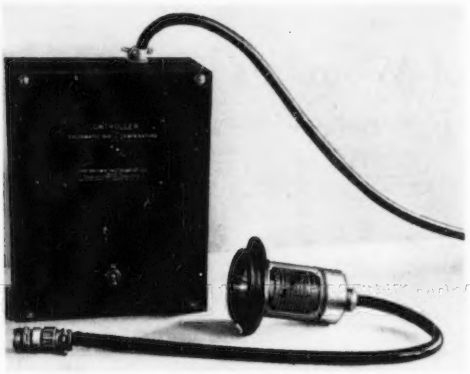

FIG. 4. *View of Brown Low Range Radiamatic and reference junction temperature controller.*

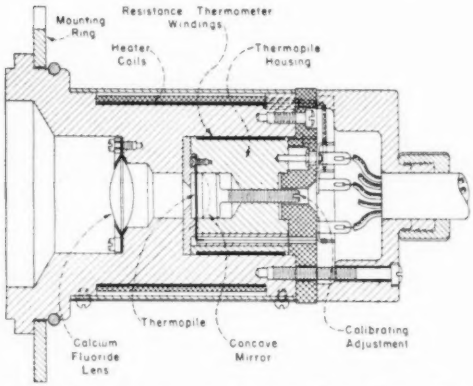

FIG. 6. *Cross-section diagram of the Low Range Radiamatic (approximate dimensions: 2¼ inches in diameter by 4⅛ inches in length).*

Components of the System.

The new pyrometer system comprises three basic components—namely, (1) the Low Range Radiamatic, (2) a reference junction temperature controller, and (3) an Electronik potentiometer. The last may be any of the conventional strip or circular-chart recording models, with or without pneumatic or electric control.

Briefly, operation of the system is as follows: Radiation of heat from the object whose temperature is to be measured is focused by a calcium fluoride lens upon a group of small thermocouples which create a minute voltage. The potentiometer receives this voltage and amplifies it in the conventional manner to operate a recording pen and, if control is included, to actuate a controlling means—such as a mercury switch.

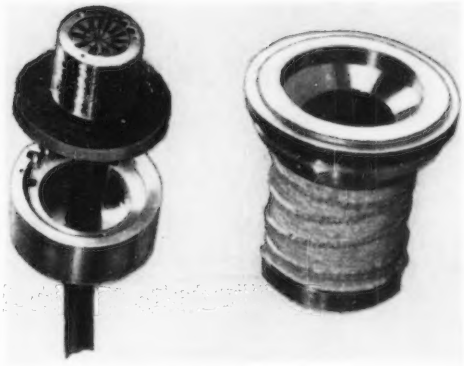

FIG. 5. *Exploded view of the pyrometer.*

To eliminate the effects of ambient temperature at the thermopile, a temperature-sensitive resistance winding and a heating element are included in the radiation detecting unit. The reference junction temperature controller operates from the resistance winding to control power to the heating element so that a constant temperature is maintained. Thus, the unit is responsive only to radiation focused upon its thermopile. The recorder has ample speed to follow the rapid response of the pyrometer to temperature changes.

The recorder is offered only with an arbitrary calibration of 0–100 evenly divided. Any attempt at temperature calibration would, of necessity, be based upon blackbody conditions and would be of little value in the majority of low-temperature applications where such conditions do not exist. Furthermore, it is usually more important to be able to reproduce a predetermined optimum temperature level from day to day than to obtain an actual calibrated temperature reading.

Because of the many applications in the textile industry for measuring the temperature of moving fabrics, and because of the adaptability of a radiation pyrometer to this service, it is believed that this measuring system will find widespread use. Although general rules can be given for its adaptation to measurement and control problems, specific application data will usually require a brief survey by a trained instrumentation engineer.

(Manuscript received March 25, 1949.)

A System for the Sizing of Women's Garments

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Ontario Research Foundation, Toronto, Canada

Abstract

Body measurements for a representative number of American women (over 10,000) have been analyzed and a system is proposed for the sizing of women's garments based on this analysis. Size classes for the entire population of women 18 years of age and over have been developed in terms of independent control dimensions which are essential for the proper fit of the particular type of garment considered.

Dimensions have been computed for standard forms set up to represent each size class of the population. The calculations involve the use of the control variables and certain dependent variables required to define the size and shape of each mannequin.

A scheme for identifying the different size classes is also proposed. This scheme takes advantage of the fact that body measurements may be divided into three categories which are virtually independent of one another.

Introduction

THE NEED for a uniform and consistent system of sizing women's garments has long been recognized. Such a system, to be satisfactory, must be based on a knowledge of the variation in body dimensions of the population to be fitted. Until recently, accurate data on this subject have been lacking [1]. A few years ago, however, a report [2] was published by the United States Department of Agriculture giving basic body measurements for a large sample of American women. This made possible a systematic approach to the problem of garment sizing, and the treatment to be discussed here makes use of the data on body dimensions and the terminology given in that report.

General Considerations

Before size classes can be set up, a decision must be reached as to the magnitude of the departure from a perfect fit which can be tolerated for each important body dimension. Once these tolerances have been chosen, the minimum number of size classes required to provide each member of the population with an acceptably fitting garment is determined. These classes may be defined in a number of different ways and various procedures may be employed to assign a prospective wearer to the appropriate class. The chief considerations in choosing a method are ease of application and freedom from overlapping classes which would tend to increase the total number above the minimum required.

It has been suggested by O'Brien and Shelton [2] that in setting up a satisfactory system for garment sizing, two measurements are needed, one as an index of the vertical body measurements and the other as an index of the horizontal measurements. Various combinations, such as stature and weight, stature and bust girth, and stature and hip girth, have been considered by these authors. The use of two measurements as controls has also been recommended in dealing with the subject of standard sizes for children's garments [3].

The approach to the sizing system here proposed is based on the supposition that a set of size classes to cover a garment of a given type should depend upon the essential body dimensions involved, rather than on some other dimensions which, although on the average closely related to them, are not directly required in specifying the size and shape of the garment.

For each type of garment the pertinent dimensions have been divided into two sets, a set of "controls" and a set of "dependent" dimensions. The selection of a set of controls has been made on the basis of the following considerations.

1. A control dimension should be one for which accuracy of fit is essential to the goodness of fit of the garment as a whole.

2. The range of variation in the population of a control dimension should be large compared to the ranges of the dependent dimensions.

3. Control dimensions should not be highly correlated with one another, but occasionally this condition conflicts with condition 1.

The choice of controls is rendered fairly simple by the fact that analysis of the data on body dimensions shows that they can be put into three categories which are virtually independent of one another, but within which correlations are fairly high. In general, lateral body dimensions are highly correlated among themselves, but their relationships with vertical dimensions are so low as to be negligible. Vertical measurements fall naturally into two independent categories, those which define the size and shape of the trunk and those having to do with length of leg. For example, the length measurements "bust to hip" and "hip to floor" are practically uncorrelated. This is apparent from the bivariate distribution of bust height minus hip height and hip height shown in Chart 1. The three categories will be referred to as the girth category, the trunk category, and the hip-height category.

Not only does this separation into three independent categories simplify the choice of controls and the assignment of size classes, but it also furnishes the basis for a simple, systematic designation of size classes. This point will be discussed later in this paper.

After the controls have been chosen, their joint distribution can be studied and their ranges subdivided into classes in the light of the allowable tolerances. Thus, there can be no overlapping of classes, in so far as the controls are concerned. Before this subdivision can be performed, certain decisions must be reached. For example, a system of classes which best covers the central portion of the population is not necessarily the most effective nucleus on which to construct a sizing system to cover the whole of the population. The aim in the present undertaking has been to devise a system, applicable to the entire population, in which the middle size classes cover a very large fraction of the whole.

The location of the points which separate the classes is also a matter in which some judgment should be exercised. It might be argued that, with respect to a given control, one class ought to be centered near the mode of its distribution, so that as large a proportion of the population as is possible may be covered by this class. This view has been rejected, however, in favor of locating a point of

Hip Height (Inches)

Bust Height Minus Hip Height (Inches)	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	Total
7								1	1			2	1			1	6
8			1				1		2			1	1				6
9	1	1		1	2	3	4	4	5	4	2	3		1			31
10				7	8	22	32	33	24	26	10	6	5				173
11		1	4	9	26	69	113	122	120	72	40	22	3	2	1	1	605
12		2	5	32	79	186	283	369	328	228	113	44	9	2	2		1682
13	1	3	7	29	117	241	483	632	594	425	194	71	30	4	1	1	2833
14			5	20	80	230	434	558	639	432	255	82	35	8	2	1	2781
15		1	2	10	41	98	201	322	323	239	139	58	27	1			1462
16			1	6	10	32	49	87	92	54	36	12	8	2	2		391
17				1	2	6	7	16	10	9	11		1				63
18						2	1		1	1		1					6
19						1											1
Total	2	8	25	115	365	890	1608	2144	2139	1490	800	302	120	20	8	4	10,040

CHART 1. *Bivariate distribution of American women according to hip height and bust height minus hip height.*

division as near as is conveniently possible to the mode. This latter procedure appears to be preferable in at least three respects.

1. It leads to a pair of central intervals, each covering about the same proportion of the population and the two together accounting for most of the population, usually 90% or more.

2. The number of classes needed to cover the entire population appears to be as small as possible.

3. The number of persons who are able to satisfy individual peculiarities and preferences, through being "borderline cases" and therefore able to choose from among two or three classes, is rendered as large as possible.

After fixing the size intervals for the control variables, the behavior of the dependent dimensions, for assigned values of the controls, can be investigated by calculating their regressions on the control variables and their standard deviations about the regressions. In no case was the standard deviation large enough so that it was considered necessary to create additional classes to take care of variation in a dependent dimension. The regressions were used to assign the average values of the dependent dimensions corresponding to each of the size classes.

Development of Size Classifications

The application of these general considerations to the setting up of size classes is considered in detail for one type of garment—namely, women's slips. Essentially similar treatment provides size data for the other garments to which reference is made subsequently.

A study of the lateral dimensions which play some part in the fit of a garment involving the trunk, such as slips, vests, and nightgowns, led to the selection of bust girth and hip girth as control variables. Chart 2 shows a grouping of the bivariate distribution [2] of bust girth and hip girth in which the tolerances for these two variables are set at 1 and 2 inches, respectively, yielding class ranges of 2 and 4 inches. These tolerances conform to present trade practice and are believed to be sufficiently small to provide garments which will fit acceptably. Since the modal bust girth for the whole population

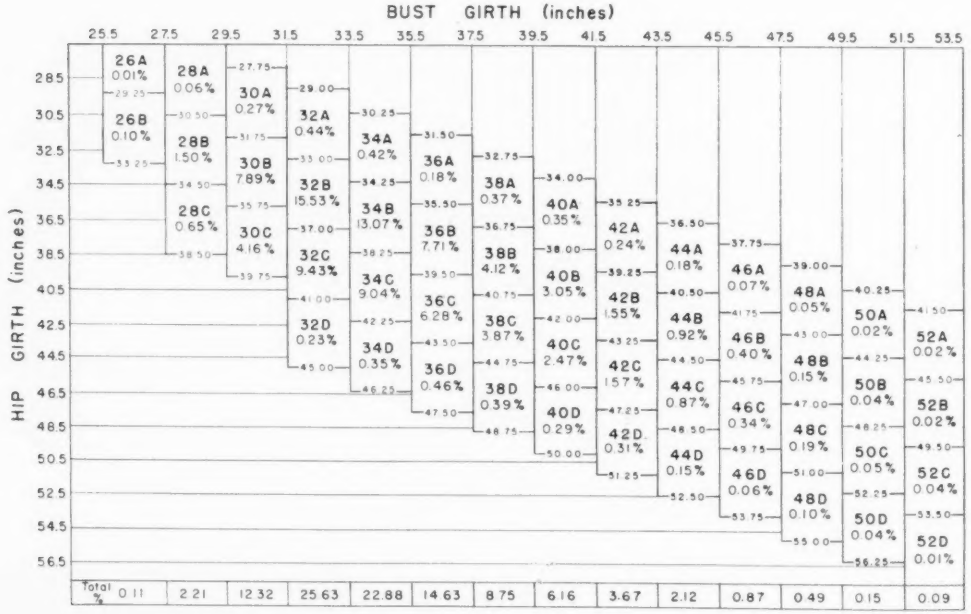

CHART 2. *Bivariate distribution of American women according to bust girth and hip girth.*

is 33.7 inches, a class limit was set at 33.5 inches so as to have the mode fall as near as possible at the division of two classes rather than at the center of one. The class limits for bust girth, as shown in Chart 2, were thus determined completely.

The hip-girth ranges, for each bust-girth class, were assigned so as to make a class limit come as close to the mode as could conveniently be arranged. While this allocation could be carried out independently for each bust-girth class, it was considered worth while to base this disposition of the hip-girth classes on a simple pattern. The regression of hip girth on bust girth shows that, corresponding to a 2-inch increment in bust girth, the hip girth increment is 1.38 inches. Therefore, it was decided to increase the values of the limits of the hip-girth classes, from one bust-girth class to the next by 1¼ inches. (A 1¼-inch increment was chosen in preference to a 1½-inch increment because it was found that the hip-girth increment corresponding to a 2-inch change in waist girth is 1.20 inches, a fact used in setting up the classes for other garments. The 1¼-inch increment was chosen as a compromise, to be used uniformly in all garments.)

The approximate proportion of the population included within the boundaries of each size class is shown as a percentage in each cell of Chart 2. Since the B and C classes together cover most of the population (somewhat over 90%) it is convenient to deal with these classes by themselves, leaving A and D classes for separate treatment.

In order to provide models which can be used as a basis for determining the dimensions of finished garments, it has been suggested [2] that standard forms or mannequins be set up to represent each size class of the population. For the B and C classes, it is proposed that the models be given the dimensions of the mid-points of the ranges. When these dimensions have been assigned, there remains only the question of assigning the values of the dependent dimensions. For women's slips, the waist-girth and neck-to-bust measurements are important dependent variables. The investigation of these variables was carried out along the following lines:

Let x_1, x_2, and x_3 represent the variables waist girth, bust girth, and hip girth, respectively, with means $\bar{x}_1$, $\bar{x}_2$, and $\bar{x}_3$ and standard deviations σ_1, σ_2, and σ_3. Let ρ_{12}, ρ_{13}, and ρ_{23} be the correlations between x_1 and x_2, x_1 and x_3, and x_2 and x_3, respectively. Then, the regression of x_1 on x_2 and x_3 may be written:

$$x_1 = \bar{x}_1 + \frac{\sigma_1}{\sigma_2}\frac{\rho_{12} - \rho_{13}\rho_{23}}{1 - \rho^2_{23}}(x_2 - \bar{x}_2) + \frac{\sigma_1}{\sigma_3}\frac{\rho_{13} - \rho_{12}\rho_{23}}{1 - \rho^2_{23}}(x_3 - \bar{x}_3)$$

and the residual standard deviation of x_1 is given by:

$$\sigma_{1.23} = \sigma_1\sqrt{\frac{1 - \rho^2_{12} - \rho^2_{13} - \rho^2_{23} + 2\rho_{12}\rho_{13}\rho_{23}}{1 - \rho^2_{23}}}.$$

When the numerical values of these quantities are substituted in the formulas, they yield:
$x_1 = 29.15 + 0.8721(x_2 - 35.62) + 0.2623(x_3 - 38.82)$;
$\sigma_{1.23} = 1.69$ inches.

This value of 1.69 inches for the residual standard deviation for waist girth indicates that, for given values of bust and hip girths, a tolerance of 2 inches in waist girth encompasses about 75% of the population, while a tolerance of 3 inches includes well over 90%. Since a good fit at the waist is not especially critical in slips, and in view of the fact that a tolerance of 3 inches includes over 90% of the population, the variation in waist girth is not considered large enough to justify the creation of additional size classes.

A similar procedure applied to the neck-to-bust dimension yields a residual standard deviation of 1.2 inches. It is believed, therefore, that no further subdivision of the population need be made to allow for a variation in this dimension.

Of the vertical dimensions, the important variables are "bust height minus hip height" and "hip height." The calculated correlation coefficient for these two quantities is -0.091 and they are, therefore, virtually independent of each other. Furthermore, both "bust height minus hip height" and "hip height" are practically independent of lateral body dimensions, and in view of this it is possible to treat each of the three categories separately.

The distribution of the bust-to-hip measurement (Chart 1) shows that 98% of the population is covered by a variation of 6 inches, from 10½ inches to 16½ inches. Since a 1½-inch tolerance is not unduly large for this dimension, two sub-classes within each bust-hip girth group having bust-to-hip measurements equal to the mid-points of the intervals 10½–13½ inches and 13½–16½ inches—namely, 12 inches and 15 inches, respectively—would serve adequately to provide a reasonably good fit with respect to this variable. Within this category of

TABLE I. DIMENSIONS FOR GIRTH CATEGORY OF MANNEQUINS FOR SLIPS—REGULAR SIZES

Girth specification	Bust girth (in.)	Waist girth (in.)	Hip girth (in.)	Neck to bust (in.)
28B	28.5	21.3	32.5	9.4
30B	30.5	23.4	33.8	9.8
30C	30.5	24.4	37.8	10.0
32B	32.5	25.4	35.0	10.3
32C	32.5	26.5	39.0	10.5
34B	34.5	27.5	36.3	10.7
34C	34.5	28.6	40.3	10.9
36B	36.5	29.6	37.5	11.1
36C	36.5	30.6	41.5	11.3
38B	38.5	31.6	38.8	11.6
38C	38.5	32.7	42.8	11.8
40B	40.5	33.7	40.0	12.0
40C	40.5	34.8	44.0	12.2
42B	42.5	35.8	41.3	12.4
42C	42.5	36.8	45.3	12.6

"bust height minus hip height," the waist-to-hip measurement is an important dependent dimension. Its standard deviation for given values of the bust-to-hip distance is, however, 0.8 inch and therefore no additional classes are needed to meet variation in this dimension.

Variations in hip height extend over a range of 6 inches for about 90% of the population. Two subclasses within each group are therefore desirable to accommodate this variable dimension.

It has been pointed out that the B and C classes cover over 90% of the population. The outlying A and D classes, which may be considered atypical, present a somewhat different problem. Unlike the B and C classes, these are occupied chiefly at one end, and for this reason it appears advisable to locate the sizing somewhat closer to the boundaries of the neighboring classes than the 2-inch tolerance on which the B and C classes were constructed. To this end, the mean hip girths for the A and D classes, rather than the mid-points of the classes, may be used. There is, therefore, some overlapping of A and D classes with B and C classes in so far as hip girth is concerned, but this is not regarded as undesirable since four classes are, in any case, necessary and the slight overlapping increases somewhat the number of individuals who are able to exercise some choice. It is to be pointed out that the data on which the A and D classes are based are scanty and there may be some inaccuracy in the calculated values of the dependent variables owing to nonlinearity of the regressions.

TABLE II. DIMENSIONS FOR TRUNK CATEGORY OF MANNEQUINS FOR SLIPS—REGULAR SIZES

Trunk specification	Bust minus hip height (in.)	Waist minus hip height (in.)
12	12.0	7.9
15	15.0	9.1

In order to include members of the outlying classes, which represent only about 10% of the population, it is necessary to almost triple the number of size classes. In view of this fact, it is doubtful that a manufacturer would attempt to make these sizes. They are, however, included here to make the sizing system complete.

Dimensions of Mannequins for Slips

Calculations have been made, according to the procedure outlined in the previous section, to determine the actual dimensions of the models required to represent the entire population. The data for the so-called regular sizes are given in Tables I to III and for the auxiliary sizes in Table IV.

The dimensions for the trunk and hip-height categories of the mannequins for slips in the auxiliary sizes are the same as those for regular sizes shown in Tables II and III.

In tabulating the data in Tables I to IV, advantage was taken of the fact that the three categories of body dimensions referred to previously are practically independent of one another. The dimensions of the models for all possible size classes may be determined by recording the different combinations of the values from each of the three categories. For example, the bust girth-hip girth class 28B may be expanded to give the following subclasses:

Size classification	Bust girth (in.)	Waist girth (in.)	Hip girth (in.)	Neck to bust (in.)	Bust minus hip height (in.)	Waist minus hip height (in.)	Hip height (in.)
28B-12-S	28.5	21.3	32.5	9.4	12.0	7.9	30.5
28B-12-T	28.5	21.3	32.5	9.4	12.0	7.9	33.5
28B-15-S	28.5	21.3	32.5	9.4	15.0	9.1	30.5
28B-15-T	28.5	21.3	32.5	9.4	15.0	9.1	33.5

TABLE III. DIMENSIONS FOR HIP-HEIGHT CATEGORY OF MANNEQUINS FOR SLIPS—REGULAR SIZES

Hip-height specification	Hip height (in.)
S	30.5
T	33.5

The other classes shown in Tables I and IV may be expanded in a similar way.

Size Classes for Other Types of Garments

A detailed discussion of one kind of garment—slips—has been given to illustrate the method employed in dividing the population into size classes and the computation of the dimensions for the mannequins to represent these classes. Consideration has also been given to other undergarments, such as nightgowns, vests, panties, and bloomers. Since size classes and dimensions for the corresponding models have been deduced in a manner similar to that used for slips, these garments will be referred to only briefly.

In determining the number of classes required for women's vests, the situation is much simpler than for slips. Only two control measurements need be considered—namely, bust girth and bust height minus hip height. The population has been divided into fourteen classes based on bust-girth intervals of 2 inches. A further subdivision into two additional sub-classes, for each bust-girth group, is necessary to allow for the fact that the variation in bust-to-hip height is approximately 6 inches for about 98% of the population. Variations in the other measurements required to define the section of the body fitted by a vest are not considered to be large enough to warrant setting up additional size classes. The pertinent dimensions of the mannequins for vests are given in Tables I and II for regular sizes and in Tables IV and II for auxiliary sizes.

In the case of panties and bloomers, seven measurements are believed to be sufficient to set up models. The control dimensions for which the question of fit is most critical are taken to be waist girth and hip girth. Tolerances for these measurements were fixed at 1 inch and 2 inches, respectively. Chart 3 shows a bivariate distribution [4] of women according to waist girth and hip girth, with the population divided into size classes. The dependent variables selected are total crotch length, anterior crotch length, and maximum thigh girth, which have residual standard deviations of 1.48 inches, 1.09 inches, and 0.92 inch, respectively.

Another dimension which might be important in garments of this type is crotch height minus tibiale height. This variable is not controlled effectively by any lateral measurements (nor indeed by any vertical measurements that would ordinarily be taken), but its standard deviation is not large (1.16 inches) and it is considered sufficient to use the same measurement for this dimension for all the size classes.

The data required to construct mannequins for panties and bloomers are given in Table V for regular sizes and in Table VI for auxiliary sizes.

TABLE IV. DIMENSIONS FOR GIRTH CATEGORY OF MANNEQUINS FOR SLIPS—AUXILIARY SIZES

Girth specification	Bust girth (in.)	Waist girth (in.)	Hip girth (in.)	Neck to bust (in.)
26B	26.5	19.2	31.3	9.0
28C	28.5	22.3	36.5	9.6
30A	30.5	22.6	31.0	9.7
30D	30.5	25.1	40.5	10.1
32A	32.5	24.7	32.3	10.2
32D	32.5	27.2	41.8	10.6
34A	34.5	26.8	33.5	10.6
34D	34.5	29.3	43.0	11.0
36A	36.5	28.9	34.8	11.0
36D	36.5	31.4	44.5	11.4
38A	38.5	30.9	35.8	11.4
38D	38.5	33.5	46.0	11.9
40A	40.5	32.9	37.0	11.9
40D	40.5	35.6	47.3	12.3
42A	42.5	34.9	38.0	12.3
42D	42.5	37.7	48.5	12.8
44A	44.5	37.0	39.3	12.7
44B	44.5	37.9	42.5	12.9
44C	44.5	38.9	46.5	13.0
44D	44.5	39.8	49.8	13.2
46A	46.5	39.0	40.3	13.2
46B	46.5	39.9	43.8	13.3
46C	46.5	41.0	47.8	13.5
46D	46.5	41.8	51.0	13.6
48B	48.5	42.0	45.0	13.7
48C	48.5	43.1	49.0	13.9
48D	48.5	44.0	52.5	14.1

The dimensions of mannequins for nightgowns are the same as those required for slips and the data are given in Tables I to IV inclusive.

Identification of Size Classes

In presenting a system of garment sizing to the consumer it is necessary to have some means of identifying the size classes. In the past, slips, for example, have been bought according to the bust girth of the wearer, and panties have been purchased according to waist girth. It will be apparent, however, that this is not sufficient to determine the size class. Other body dimensions are also required before a proper classification can be made.

It is proposed, therefore, that suitable designations be assigned to each of the control variables. It is suggested that bust-girth and waist-girth classes be labeled according to the lowest even integer falling within the particular class interval. The four hip-girth classes have been labeled A, B, C, and D. The two classes in the trunk category might well be designated by their mid-points—12 and 15—and the two classes in the hip-height category have been assigned letters—S (short) and T (tall).

The complete size designation of a garment could be represented by a code consisting of two or four parts, depending upon the number of body measurements needed to classify a woman. For example, a slip might be labeled *36B-12-T* or *34C-15-S*, and the identification for a pantie might be 32 B or 34 C.

The code system proposed for referring to size classes is arbitrary, but it is orderly and takes into account all combinations that conceivably could be encountered. The procedure is partly illustrated by the upper number in each rectangle shown in Charts *2* and *3*.

Dimensions for Finished Garments

In translating the measurements of the different mannequins into the actual dimensions required for finished garments, consideration should be given to factors such as style, comfort, and other clothing over which the garment may be worn. In this way, scope is allowed for the preferences of individual manufacturers in styling garments. It should be pointed out, however, that regardless of the style selected, this system ensures that all manufacturers will be making garments to fit the same set of

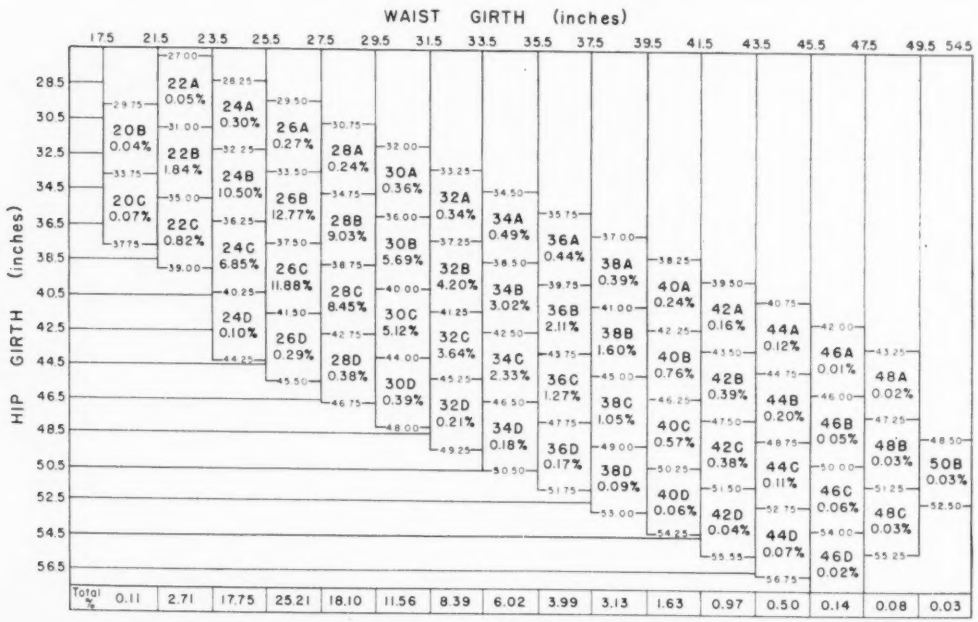

CHART 3. *Bivariate distribution of American women according to waist girth and hip girth.*

TABLE V. DIMENSIONS OF MANNEQUINS FOR PANTIES AND BLOOMERS—REGULAR SIZES

Size classification	Waist girth (in.)	Hip girth (in.)	Maximum thigh girth (in.)	Total crotch length (in.)	Anterior crotch length (in.)	Crotch height minus tibiale height (in.)
22B	22.5	33.0	18.7	26.2	12.7	11.3
24B	24.5	34.3	19.4	27.0	13.2	11.3
24C	24.5	38.3	22.0	28.8	13.9	11.3
26B	26.5	35.5	20.2	27.9	13.6	11.3
26C	26.5	39.5	22.7	29.6	14.3	11.3
28B	28.5	36.8	21.0	28.7	14.1	11.3
28C	28.5	40.8	23.5	30.4	14.8	11.3
30B	30.5	38.0	21.7	29.5	14.5	11.3
30C	30.5	42.0	24.2	31.2	15.3	11.3
32B	32.5	39.3	22.5	30.3	15.0	11.3
32C	32.5	43.3	25.0	32.1	15.7	11.3
34B	34.5	40.5	23.2	31.1	15.5	11.3
34C	34.5	44.5	25.7	32.9	16.2	11.3
36B	36.5	41.8	24.0	32.0	15.9	11.3
36C	36.5	45.8	26.5	33.7	16.6	11.3
38B	38.5	43.0	24.7	32.8	16.4	11.3
38C	38.5	47.0	27.3	34.5	17.1	11.3

TABLE VI. DIMENSIONS OF MANNEQUINS FOR PANTIES AND BLOOMERS—AUXILIARY SIZES

Size classification	Waist girth (in.)	Hip girth (in.)	Maximum thigh girth (in.)	Total crotch length (in.)	Anterior crotch length (in.)	Crotch height minus tibiale height (in.)
20B	20.5	31.8	17.9	25.4	12.2	11.3
20C	20.5	35.8	20.4	27.1	12.9	11.3
22C	22.5	37.0	21.2	27.9	13.4	11.3
24A	24.5	31.5	17.7	25.8	12.7	11.3
24D	24.5	41.0	23.7	30.0	14.3	11.3
26A	26.5	32.5	18.3	26.6	13.1	11.3
26D	26.5	42.5	24.6	30.9	14.9	11.3
28A	28.5	33.8	19.1	27.4	13.6	11.3
28D	28.5	43.8	25.4	31.7	15.3	11.3
30A	30.5	35.0	19.8	28.2	14.0	11.3
30D	30.5	45.0	26.1	32.5	15.8	11.3
32A	32.5	36.0	20.4	28.9	14.4	11.3
32D	32.5	46.5	27.0	33.5	16.3	11.3
34A	34.5	37.3	21.2	29.7	14.9	11.3
34D	34.5	47.8	27.8	34.3	16.8	11.3
36A	36.5	38.5	21.9	30.6	15.4	11.3
36D	36.5	49.0	29.6	35.1	17.2	11.3
38A	38.5	39.8	22.7	31.4	15.8	11.3
38D	38.5	50.3	29.3	35.9	17.7	11.3
40A	40.5	41.0	23.5	32.2	16.3	11.3
40B	40.5	44.3	25.5	33.6	16.9	11.3
40C	40.5	48.3	28.0	35.3	17.6	11.3
40D	40.5	51.5	30.1	36.8	18.1	11.3
42A	42.5	42.0	24.1	32.9	16.7	11.3
42B	42.5	45.5	26.3	34.4	17.3	11.3
42C	42.5	49.5	28.8	36.2	18.0	11.3
42D	42.5	52.8	30.8	37.6	18.6	11.3

mannequins and these models will, in turn, reflect the distribution of body shapes of the entire population of women.

Summary

A system has been developed for the sizing of women's garments which makes use of the distributions of body measurements for a large sample of American women. It is based on the assumption that the size classes to cover a garment of a given type should depend on the pertinent body dimensions, rather than on some other dimensions which may, on the average, be closely related to them, but which are not directly required in specifying the size and shape of the garment.

Control measurements have been selected for slips, nightgowns, vests, panties, and bloomers, and the whole population has been divided into size classes in accordance with tolerances which conform to present trade practice. The behavior of the dependent dimensions, for assigned values of the controls, was investigated by calculating their regressions on the control variables and their standard deviations about the regressions. In no case was the standard deviation large enough to require additional size classes to take care of the variation in a dependent dimension. The regressions were used to assign the average values of the dependent measurements corresponding to each of the size classes.

Dimensions are given for the mannequin representing each size class for the five types of garments considered. A system for identifying the different size classes has also been proposed. It is based on the fact that body measurements fall into three categories which are virtually independent of one another.

Acknowledgment

The authors gratefully acknowledge the assistance of Courtaulds (Canada) Limited, who sponsored the fellowship under which the work on this project was carried out.

Appreciation is expressed to Mrs. Bess V. Morrison of the United States Bureau of Human Nutrition and Home Economics, who very kindly supplied the bivariate distributions which do not appear in reference [2].

Thanks are also due to Dr. A. C. Goodings for his continued interest and help, and to members of the staff of the Textile Department, Ontario Research Foundation, who have assisted in this work.

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(*Manuscript received February 14, 1949.*)

Dynamic Studies of Carpet Resilience*

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Abstract

The problem of measuring the dynamic properties of a carpet is carried through several different steps which lead to the development of dynamic load measuring equipment designed to evaluate differences of carpet construction.

IN RECENTLY PUBLISHED PAPERS by R. M. Hoffman [1] and W. J. Hamburger [2] it was pointed out quite clearly that in completely defining the different physical attributes one does more than merely attempt to place material (in this case a carpet) on a resilience scale. The present work is an attempt to separate out one of these physical properties and quantitatively measure it.

The first part of this work has already been reported [3]. However, it is worth while to repeat some of this material. It was reported that when a person walks on a carpet, it is subjected to rapid loading at the rate of about 120 pounds per square inch per second up to a peak load of 12 pounds per square inch, and that this load is then withdrawn at the same rate. In addition, there were reported the results of compressometer measurements of energy absorption upon carpets under static conditions. These latter are discussed in more detail later in this paper.

The first problem in devising a dynamic test was to find out how the fibers are actually bent when a person walks on a carpet. The most obvious way of finding out was to take high-speed photographs of someone walking on a carpet. Figures 1, 2, and 3 show selected results from the series of photographs. A Speed Graphic camera and a Wabash portable high-speed electronic flash outfit were used. The camera shutter was opened manually and the flash bulb was tripped as the person was walking past the camera by a signal from a photocell-amplifier set-up. The duration of the flash is about 1/5,000 of a second, which permitted a "frozen" picture of the action to be taken. Some of the things which can be seen from the photographs were anticipated while others were completely new. For instance, it was thought that the forward component of motion would bend all the pile fibers in the same direction; but it was not realized over how wide an area this would be true. It can be seen by examination of the photographs that the fibers do not all bend alike and that they act in groups rather than singly. This proved to be an important clue to the performance of material in the form of pile fabric, for it pointed up a fact which was known but had never been demonstrated before—that the interfiber relationships, such as surface fiber friction, fiber crimp, and the energy absorption properties of groups of fibers, are equal in importance to the elastic performance of single fibers. The problem of stress analysis is still unsolved because it cannot be seen from the photographs what was happening to the individual fibers under load.

For the moment, a dynamic test seemed impractical, and therefore a static test was arranged to replace it. Figure 4 shows what was found. The carpet was placed in unpolymerized plastic and a 40-gram weight was placed on top of it and left there. After the material had polymerized, it was cut through the middle and polished with rouge so that the photographs could be made. It thus represents a cross section through the carpet with the pile fibers bent by the application of a static weight. It, of course, had been visualized before the picture was taken that the tops of the fibers would lie flat after the application of the load. There were, however, several things which had not been realized: first,

* This paper was presented before the Fiber Society meeting at Fontana Village, North Carolina, on April 23, 1948.

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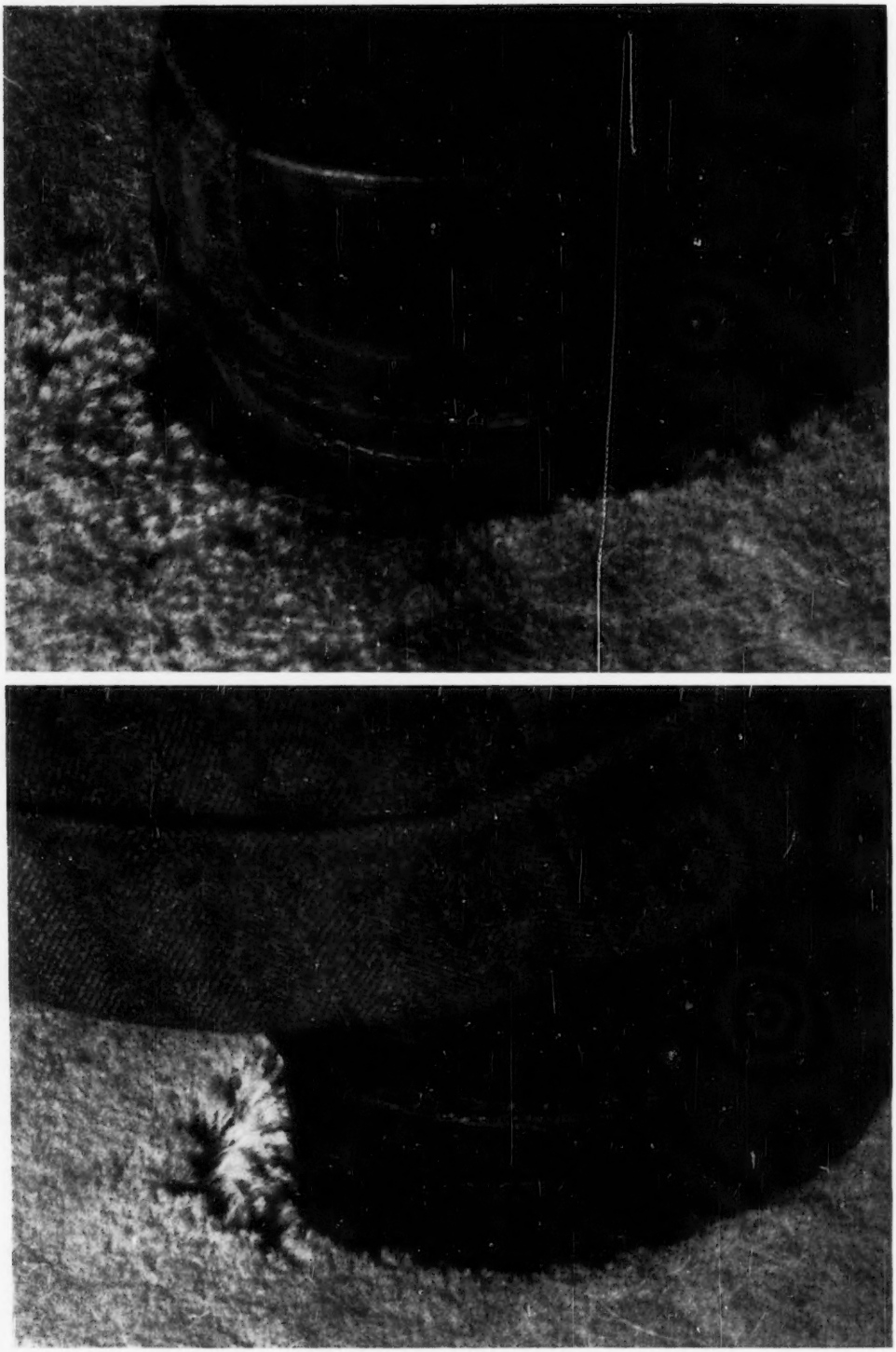

FIGS. 1 and 2. *High-speed photographs of impact made on a carpet while it is being walked upon.*

that the backing yarns provide a stiff enough structure to hold the lower portion of the pile in a nearly vertical position; second, that the yarns act as a unit rather than separately; and, third, that the effect of a concentrated load is spread over an appreciable area. Now it should be realized that this may not be the same condition as that which takes place upon dynamic loading—that it is merely an approximation, but it is a start. Work is continuing on this phase of the problem and it is hoped that a technique can be developed to demonstrate the dynamic loading picture.

It was concluded that the backing played an important part in determining the over-all elastic properties of the carpet; therefore, a method was developed for measuring separately the moduli of the carpet face and backing. In brief, it was postulated that the carpet face and backing could each be considered as a separate spring loaded in compression and that the elastic performance of the carpet was the same as that of the two springs placed in series. The spring constant of the carpet back was made very large by coating the carpet back with a resin which penetrated through the backing and up to the base of the tufts. It was then easy to calculate from load-deflection data the ratios of stiffness for the back and for the face of the carpet. This was done for two types of carpet with load-deflection data obtained by the use of the Schiefer Compressometer [4], with readings taken once every 15 seconds. Once again, static measurements were dealt with rather than dynamic, because suitable instrumentation was not available for the latter—however, it is intended to repeat the tests dynamically. Figure 5 shows the load-deflection curves for a rather inexpensive grade of Axminster carpet. Figure 6 shows the stiffness ratio K plotted as a function of load (from Figure 5). Some very interesting results were obtained. It can be seen that at low loads, where the deflection of the pile just started, the effect of the back of the carpet is not noticeable. However, the ratio rises rapidly to a point where the back is nine times as stiff as the face. Then as the pile is crushed, the ratio drops to an almost constant value of 2.3 and remains there up to the loading limit of the instrument. This was quite a surprising result to the writer because he had always supposed that the backing contributed very little to the elastic performance of the carpet, whereas this test showed that it was only about twice as stiff as the face in the "operating" range (about 7.5 load units). This opens up an interesting possibility for effecting changes in the elastic characteristics of this type of floor covering without

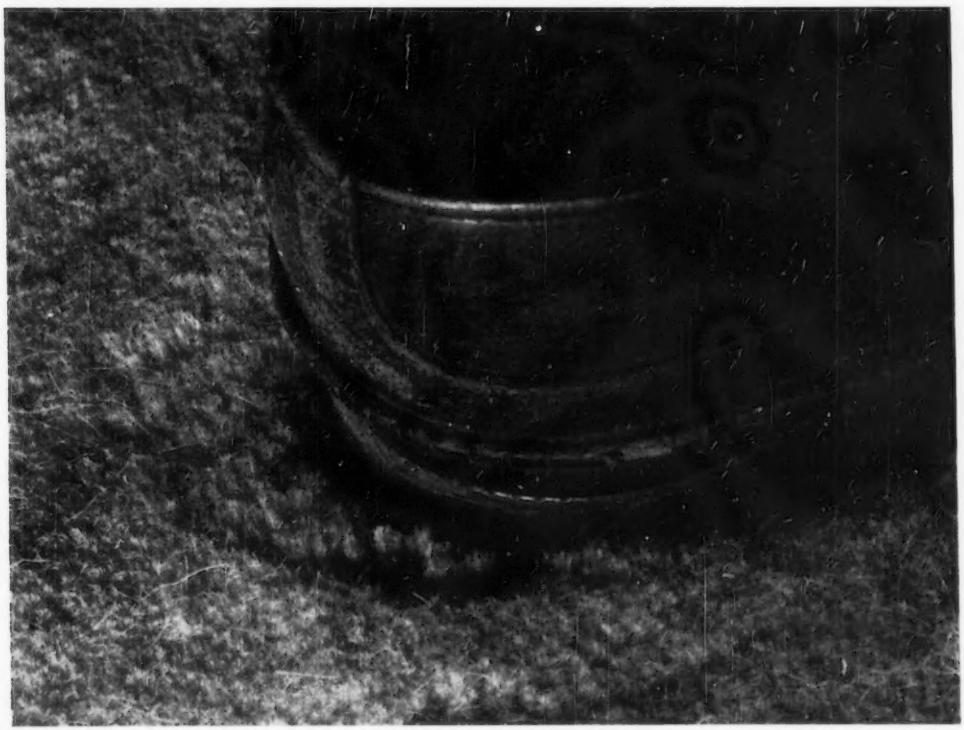

FIG. 3. *High-speed photograph of impact made on a carpet while it is being walked upon.*

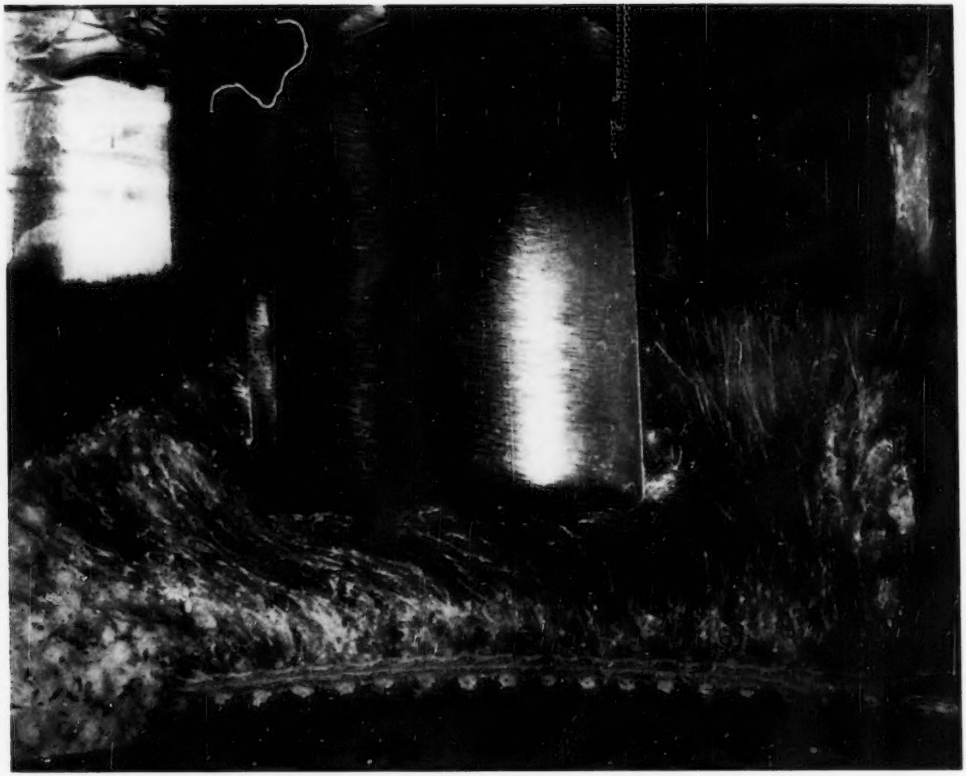

FIG. 4. *Cross section of statically loaded carpet.*

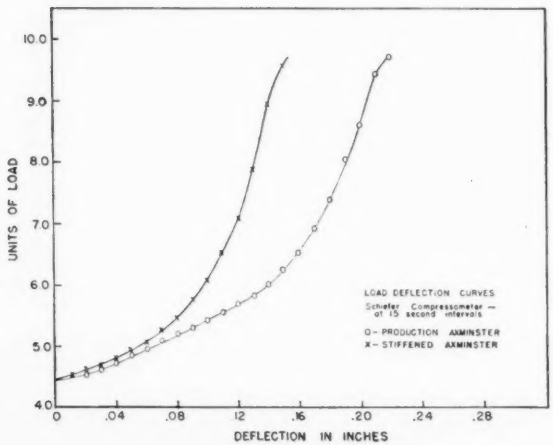

FIG. 5. *Loading diagram, Axminster carpet.*

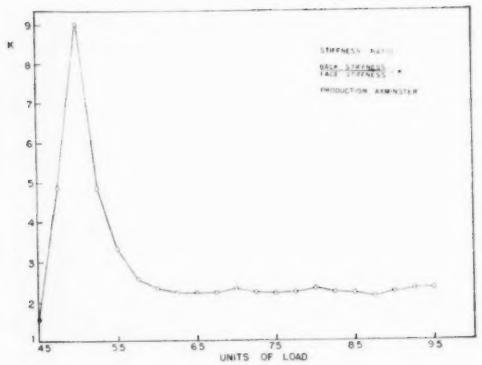

FIG. 6. *Calculated stiffness ratio, Axminster carpet.*

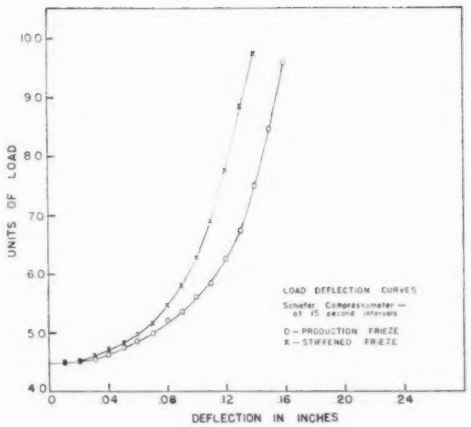
UNITS OF LOAD
DEFLECTION IN INCHES
LOAD DEFLECTION CURVES
Schaefer Compressometer — at 15 second intervals
O – PRODUCTION FRIEZE
X – STIFFENED FRIEZE

FIG. 7. *Loading diagram, frieze carpet.*

changing the face of the carpet. The test was repeated on a frieze or hard-twist type of carpet and quite different results were obtained, as might be expected. Figures 7 and 8 show these results in some detail. Reference to the other deflection curves shows that these carpets are stiffer than their counterparts for the Axminster carpet. Inspection of the curve which plots K, the stiffness ratio, as a function of load shows that while it varies between 4½ and 6½ it is more or less a straight-line relationship. Thus, there is no load condition under which the pile is extremely soft, nor does it become compressed enough under normal loads to reduce K below the lowest value of 4½. These results, it must be remembered, are based upon load-deflection curves measured statically, one reading being taken every 15 seconds with the deflection changed a fixed amount between each reading and the next. The situation may be markedly changed when it is possible to make measurements dynamically and under actual service conditions. However, the rather major role of the back construction cannot be denied.

The first attempt at taking dynamic measurements was a direct result of the experiments which have been mentioned above. It was assumed that it should be possible to measure one factor of the carpet resilience if we measured its ability to absorb energy under simulated service conditions. A test instrument was constructed which is shown in Figure 9. This instrument is essentially a freely falling weight, with a means for indicating the position of the weight as a function of time and permanently recording it. Of particular interest is the Schaevitz

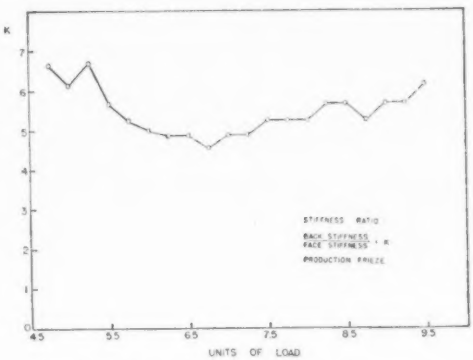

FIG. 8. *Calculated stiffness ratio, frieze carpet.*

linear differential transformer,* the output from which is a function of the position of the movable core. When this output is recorded on an oscillograph, it is then possible to make the necessary measurements. Figure 10 shows a block diagram of the circuit used. It might be mentioned that the circuit was excited by a 1,000-cycle-per-second audio oscillator at an input level of about 10 volts. With the loading conditions used, the output of about 3–4 volts was amplified and recorded.

Figure 11 shows the actual instrument set up for operation. The transformer in use was designed for a linear range of $\pm \frac{1}{4}$ inch, but our calibration

* A patented device manufactured by Schaevitz Engineering Co., Crescent Boulevard at Drexel Avenue, Pennsauken Twp., Camden, N. J.

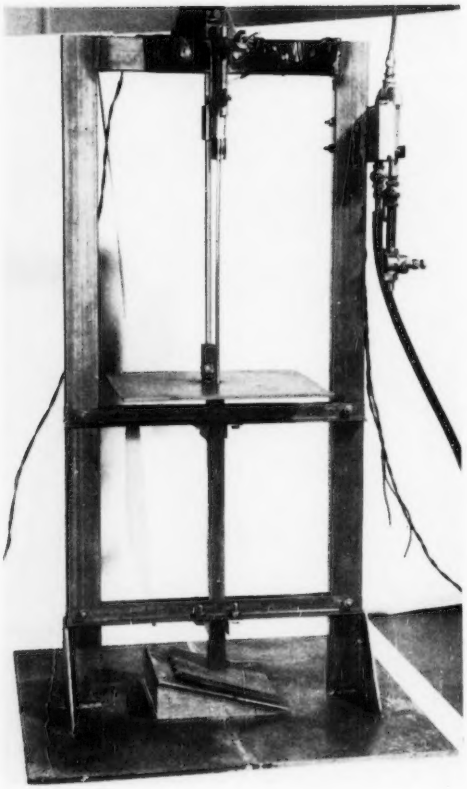

FIG. 9. *Dynamic loading apparatus.*

showed satisfactory linearity over ± 5/8 inch. The static weight of the foot is 12.5 pounds and the area is 1 square inch, which roughly corresponds to the conditions measured last year and previously reported.

The type of traces obtained on a good-quality velvet carpet is shown in Figure 12. These two traces were falls made from different heights onto different carpet constructions. That the initial heights were different can be seen by the positions from which the pen appeared on the charts. (The pen moved from left to right across the charts.) That the carpet constructions were different may be observed by the differences in shape of the curves—different deflections from the electrical zero point, different heights to the rebound, and different final thicknesses. The 60-cycle timing wave on the second

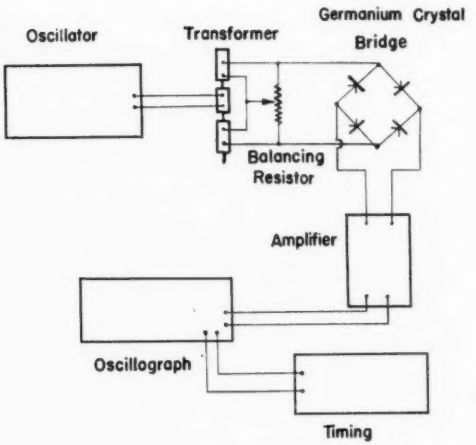

FIG. 10. *Block wiring diagram, deflection measuring equipment.*

channel of the oscillograph in each case serves as a time reference and makes possible calculation of rates of loading. The maximum rate for this series of tests was approximately 20 inches per second. The interpretation of the curves was not difficult for these particular carpet constructions; *i.e.*, constant total thickness and wool varying densities.

Reference to some of the original work of Beckwith [3] shows that he concluded that the work of compression, although not an effective measure of service utility for mixed fibers after crushing by service, did show the effect of form or construction difference. On this basis, it was decided to measure the ability of the individual carpet to absorb energy imparted to it by the falling weight. From fundamental physical laws it can be easily shown that if a series of carpets are deflected to the same extent (*i.e.*, the same physical amount) and the heights through which the weight had to fall to produce this deflection is measured, the ratio of height will be in direct proportion to the amounts of energy necessary to produce the deflection. For the purposes of this measurement it was assumed that the initial deflection was the important quantity, and on this basis the results for two quite different carpets could be plotted. This is shown in Figure 13. In theory, then, it is necessary only to choose a fixed deflection, and then the ratio of heights above the carpet will provide a measure of the ability of the carpet to absorb energy.

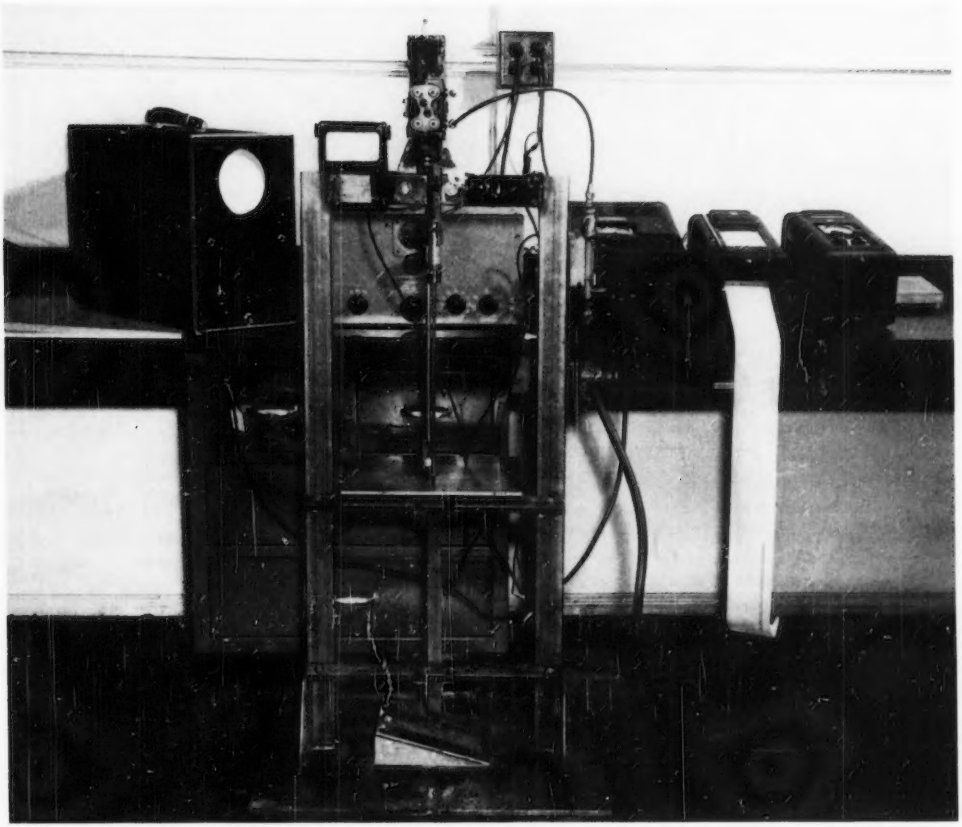

FIG. 11. *Complete measuring set-up for dynamic deflection measurement.*

The two samples for which complete curves were plotted have pile densities of 24.8 (circles) and 40.4 grams per cubic inch (upright triangles) and constant pile heights of 0.19 inch. The remainder of the densities plotted for 0.75 inch were not complete enough to permit curves to be extended. It is interesting to see that the rate of loading and/or amount of energy have a very definite effect upon this ratio. Thus, at a deflection of 0.175 inch the energy ratio is 3:1, while at a deflection of 0.275 inch the ratio is 1.3:1. This is not surprising, since in the first case, theoretically at least, the back of the carpet was not reached, while in the second it most certainly was and was also considerably compressed.

It may further be mentioned that in his original work with compressometer measurements on these same carpets Beckwith measured an energy ratio of 1.42:1 with the compressometer, thus lending credence to the theory that static measurements should not be relied upon to tell the entire story. There is no real reason to believe that the linear relationship drawn in should hold over the entire range of deflections; but the instrumentation was not sensitive enough to show any other definite shape to the curve, so therefore a straight line was chosen. Recent work of R. B. Finch [5] shows that it will not hold at low rates of loading. It is also theoretically possible to analyze the deflection curve more completely and obtain an equation which represents

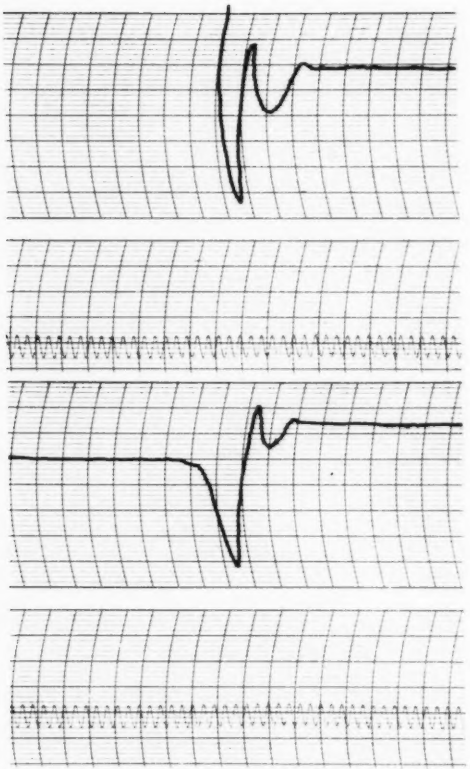

FIG. 12. *Sample records—dynamic deflection equipment.*

the work done in stopping the weight rather than the energy absorbed during its initial descent. This is still under examination, since the equation is much more complicated and of the form:

$$W = m \int_0^t \frac{d^2y}{dt^2} \cdot \frac{dy}{dt} \cdot dt,$$

which does not seem to lend itself to easy analysis.

Summary

The purpose of this paper is to describe the development of a method for measuring the energy absorption ability of different types of carpet and to present the initial results obtained. It has been concluded that with revision of the instrumentation the method is practical, and that even in its present form it is possible to measure differences between carpets of different constructions. Furthermore, because of the physical form of a pile floor covering, the elastic constants will depend upon the loads involved and, in the future, testing must make provision for more careful measurement of service conditions and for specification of testing conditions. The principles of the method of test should be of interest to manufacturers of other types of textiles wherever impact loads are involved.

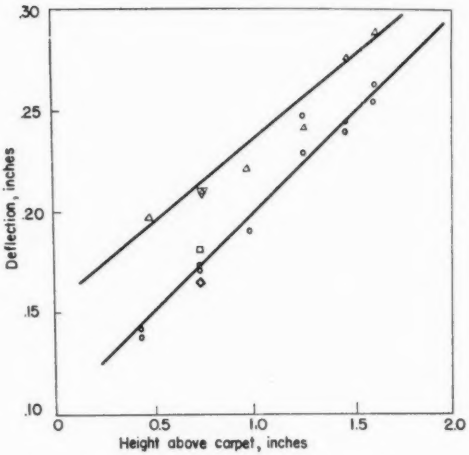

FIG. 13. *Instantaneous maximum deflection as a function of input energy—for two carpets.*

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(*Manuscript received March 18, 1949.*)

Certain Variations in the Structure and Properties of Natural Cellulose Fibers*

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Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture

NATURAL CELLULOSE FIBERS constitute 70 to 80 percent of all fibers used by man. Although they are all obtained from the plants that grow about us, they have widely different origins and varied functions in the organisms from which they are derived. They may be classified according to use by man as: (*a*) textile fibers; (*b*) cordage fibers; (*c*) upholstery fibers; (*d*) packing fibers, etc. Since certain of them may be used for more than one type of product, or even in all of the groups listed, a more logical grouping may be made according to origin. The more commonly known fibers may be classified as follows:

Origin	Examples
1. Seed hairs	Cotton and milkweed floss
2. Pod fibers	Kapok
3. Hull or fruit fibers	Coir
4. Leaf (hard) fibers	Abaca and sisal
5. Bast (soft) fibers	Flax and jute
6. Stem fibers	Spanish-moss
7. Root fibers	Broomroot

Within each of these groups there are wide differences between fibers in size, shape, and physical properties. They may be compared also as to fiber length, cell structure, and whether or not they are: (*a*) single-cell fibers, such as cotton, kapok, and ramie when fully degummed; or (*b*) multicellular fibers, such as abaca or jute and Spanish moss.

Certain of the bast fibers, such as ramie, flax, and American hemp, can be used either in strands of many cells or separated into single cells.

Each general type of fiber has certain characteristics that distinguish it from other types. However, within a given group wide differences in physical properties are not uncommon. These differences may be due to: (*a*) the species or variety of plant; (*b*) the growth conditions; (*c*) the cell-wall constituents; and (*d*) their physical make-up or fine structure.

In single-cell fibers—for example, cotton—the physical properties are dependent upon the size and shape and the chemical and physical structure of the cell wall, whereas in multicellular fibers, such as abaca (Manila hemp), the binding layer, designated "intercellular material," between the cells is a vital element in the system.

The cotton fiber, although consisting of a single cell, is not simple. The cell wall is composed of (1) primary wall, (2) outer layer of the secondary thickening, (3) central layers of the secondary thickening, (4) when fully mature, the inner layer of the secondary wall, and (5) the lumen with the residue of the protoplasm (see Figure 1).

The primary wall of the cotton fiber contains, in addition to cellulose, waxes and pectic materials and, no doubt, other compounds. The relatively high shrinkage of this layer of the cell wall with changes in moisture content indicates that a large percentage of the cell-wall substance is non-crystalline material. Extraction of the waxes and pectic materials increases the tendency to shrink upon drying but does not destroy the continuity of the cell wall.

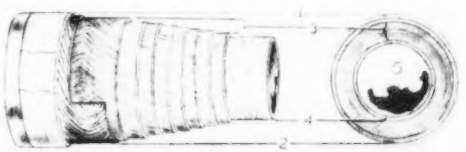

FIG. 1. *Diagram of cross section and telescoped longitudinal section of cotton fiber: (1) primary wall, (2) first layer, (3) central layers, (4) inner layer of the secondary thickening, and (5) the lumen with the residue of the protoplasm.*

* Presented before the Science Society of Florida at Bell Glade, April 4, 1947.

† Present address: Anderson, Clayton and Company, Houston, Texas.

The multicellular fibers contain all the parts listed for cotton and, in addition, an intercellular material that binds the cells together (Figure 2). Since most leaf and bast fibers contain lignin, the intercellular layer is frequently highly lignified.

The physical properties, and therefore the use value of these fibers, vary with the structure of the cell walls and, in the case of multicellular fibers, the binding layer between them. Variations in the orientation of the crystalline cellulose in the central layers of the secondary thickening can be measured with x-ray diffraction technique. In general, the cellulose in natural fibers consists of long chains made up of glucose anhydrides linked through the 1 and 4 carbons. These long, thread-like molecules crystallize to form the so-called crystallites, long, needle-shaped filaments, which, in turn, are bound together in bundles to form the fibrils which may extend the full length of a cell (Figure 3). Within a given fibril the long axes of the cellulose molecules (that make up the crystalline phase), those of the crystallites, and that of the fibril of which they are a part lie parallel with each other. The molecules apparently are held together in the crystal by so-called "hydrogen bonds." The crystallites, in turn, are bound together by cellulose molecules which are not in the crystalline phase but may be bonded to the crystallites at certain points. They lie, for the most part, between the crystalline units in a brush, heap-like structure with an occasional hydrogen bond where one molecule crosses another.

In these amorphous (non-crystalline) regions other substances than cellulose may exist. Among other things, lignins, pentosans, pectic substances, and waxes are very common. Certain of these materials, particularly cotton wax, may be crystallized.

The tensile strength of natural cellulose fibers varies with the arrangement of these elements in the cell wall. In general, the fibrils (and therefore the crystallites) spiral around the fiber. As the long axis of the fiber and that of the crystallites deviate from each other, the arcs in the x-ray diffraction pattern resulting from the 002 plane in the crystal, for example, tend to lengthen, and vice versa (see Figure 4). The tensile strength of cotton may be estimated from the x-ray diffraction patterns, although the crystalline phase from which they are derived appears to be discontinuous, being dispersed in an amorphous matrix except for the molecules that may be a part of more than one crystallite. The crystallites and, in turn, the fibrils are very long in comparison with their breadths; therefore, the friction along their surfaces may be great enough to cause rupture of the crystal when the fiber is broken. In single-celled fibers, such as cotton, ramie, and even flax when completely defibered, an index of the strength of each type may be obtained from the spiral arrangement of the crystalline cellulose in relation to the fiber axis. The relationships are dif-

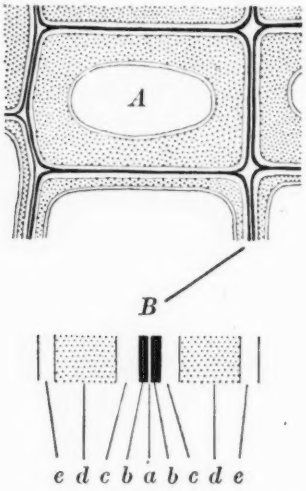

FIG. 2. *Diagram of cross section of* (A) *one entire cell and parts of others;* (B) *sections of adjacent walls more highly magnified:* (a) *intercellular material,* (b) *primary wall,* (c) *outer layer of secondary wall,* (d) *central layer of secondary wall, and* (e) *inner layer of secondary wall.* (*Courtesy Kerr and Bailey.*)

FIG. 3. *Diagram representing a cellulose molecule, a crystallite, and a section of a fibril in native cellulose. The straight, parallel lines represent the crystalline phase, and the wavy lines, the amorphous phase of the cellulose.*

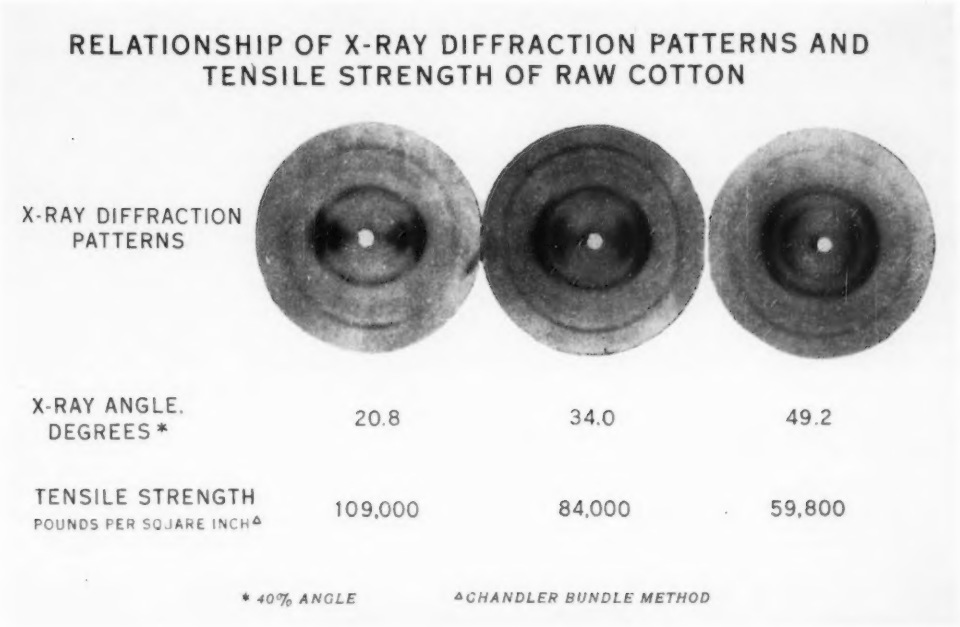

FIG. 4. *X-ray diffraction patterns showing variations in spiral structure of cotton fibers. The x-ray angles and the tensile strengths indicate the inverse relationship usually found in the natural cellulose fiber.*

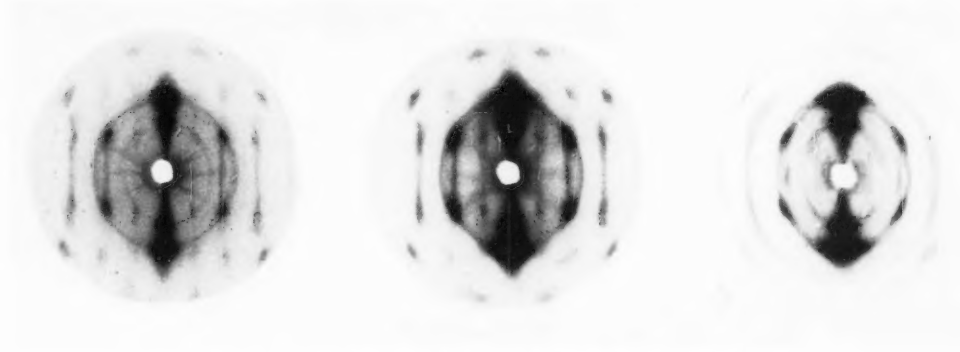

FIG. 5. *X-ray diffraction patterns of hemp, flax, and ramie in the order of increasing spiral angles from left to right.*

ferent, however, for each fiber type and, in the case of cottons, the species and even varieties may differ.

Among the samples of bast fibers studied here, hemp shows slightly shorter arcs—*i.e.*, the crystallites lie more nearly parallel with the fiber axis than they do in the flax or ramie samples (see Figure 5). The longer the major equatorial arcs, the greater the angle between the long axis of the crystallites and the fiber axis and vice versa. The cellulose crystallites lie more nearly parallel with the fiber

axis in the hemp than in the flax or ramie samples represented here.

The leaf, or hard fibers, contain more lignin and other non-crystalline materials; thus, more general background radiation appears in the x-ray diffraction patterns than in those of the purified bast fibers used in this study. The spiral angle of the crystalline cellulose, however, may be highly organized but is not so nearly parallel with the fiber axis as that of the bast fibers (Figure 6).

There is a very wide range of fiber structures, particularly in the stem and root fibers used in upholstery (Figure 7). The spiral angle in Spanish moss is great enough to be resolved into two pairs of arcs—one from each of the opposite walls.

Cotton, as indicated by the diagram in Figure 4, shows the greatest variation in spiral angle of any fiber studied. The x-ray angles vary from about 18° to 52° in the samples studied in the laboratory thus far. These angles are only indices of the true spiral, but they are indicative of the enormous differences to be found. Even wider differences may be expected when all of the wild species of cotton are examined.

Preparation of sample is extremely important in the multicellular fiber tests. In ordinary flax, jute, and hemp, for example, the degree of ret may influence the strength of the fiber to the extent that no relationship can be established between the structure and the strength. Similarly, the condition of growth and the methods of decortication affect such fibers as abaca and sisal. All fibers are weakened by biological decay and sunlight. Since the chemical make-up of the fibers is different, they respond differently to exposure to the weather, particularly in moist places. Fibers high in lignin content, such as coir, are more resistant to fungi and bacteria than cotton fiber, for example, which has a high percentage of cellulose and no lignin. In general, fibers with a high percentage of lignin tend to be stiff and harsh, whereas those composed principally of cellulose, such as cotton, may be firm but flexible. Ramie, when degummed, is essentially pure cellulose, but it may be relatively stiff compared with

FIG. 6. *X-ray diffraction patterns of abaca, sisal, sansevieria, and henequen in the order of increasing spiral angles from left to right.*

FIG. 7. *X-ray diffraction patterns of kapok, arundinaria, and Spanish moss in the order of increasing spiral angles from left to right. Note the heavy radiation from the amorphous material in kapok, and the tendency for double maxima in arundinaria and Spanish moss.*

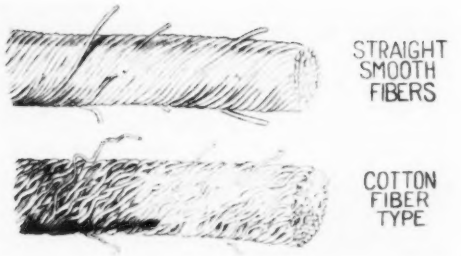

FIG. 8. *Two yarns of the same diameter, one spun from smooth straight fibers, and the other from crimped and convoluted cotton fibers. The fibers in the first yarn will slip when tension is applied, whereas in the latter yarn the fibers lock together as they become taut.*

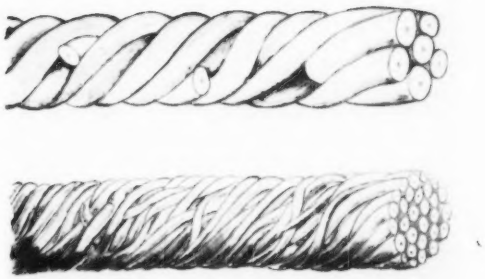

FIG. 9. *Two yarns of equal size, one made of coarse fiber, and the other of relatively fine fiber. In the latter yarn more fibers are bound within the yarn.*

cottons that have much larger spiral angles. The degree of crystallinity of the cellulose may also influence the rigidity of the fiber.

The spinnability and, to a large extent, the use value of a fiber is dependent upon its shape or contour. The ratio of breadth to length is very important and determines the type and size of yarns into which the fiber can be spun. Fibers with pronounced crimps and rough surfaces felt better and can be spun into relatively stronger yarns than smooth straight fibers (see Figure 8).

The effects of fineness vary with the product being produced, but, in general, the finer the yarn spun the more important fiber fineness becomes. This is particularly true if the length of the fiber is limited. Mechanically, more of the fine fibers are bound into the interior of the yarn than of the coarse fibers (see Figure 9). Yarn appearance and uniformity may be influenced by the regularity of fiber size and degree of cell-wall thickness as well as by length. Very coarse, thick-walled fibers tend to tangle with thin-walled fibers to form neps.

The surface friction may be an asset in the spinning process, but if it is due to the presence of gritty substances such as residues of encrusting materials it may cut the adjacent fibers and cause weakness in the yarn upon flexing. For most purposes, the yarns or fabrics are flexed under load or in use. When a member, such as a thread, is bent, one side is placed under tension and the other under compression. If a fiber is rough, it may bind and be ruptured rather than slip until all elements are under essentially equal stress. Certain types of cotton fibers have a pronounced crimp; others have, in addition, convolutions (auger-like twists), which reverse

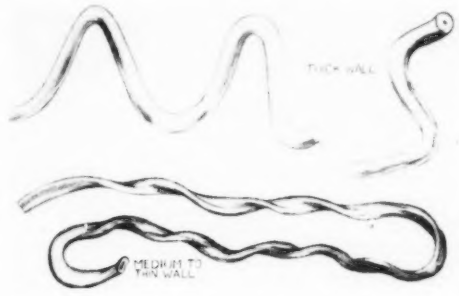

FIG. 10. *Cotton fibers showing a highly crimped thick-walled fiber and one of medium cell-wall thickness with convolutions.*

periodically and tend to grip adjacent fibers in a yarn and thus increase their spinnability (see Figure 10).

The surface friction of bast fibers, such as ramie, may be regulated by leaving a residue of the intercellular material, so-called "gums," on the fibers. If they are degummed to the extent that the individual fibers are separated, crimp probably will be more desirable than surface friction. Where appropriate spinning equipment is available, length of fiber in ramie may overcome, to a large degree, lack of crimp and low surface friction. Long fibers can be spun with fewer turns per inch, thus avoiding shear failures which are so disturbing in tight twisted ramie staple fibers.

The degree of ret regulates the non-fibrous material and influences, to a large extent, the fiber length and the spinnability of flax, hemp, and other bast fibers in textiles, and jute-like fibers in burlap and rugs.

(*Manuscript received September 16, 1948.*)

ABSTRACTS

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A list of periodicals, the abbreviations used in reference to articles, and the addresses of publishers of English-language publications is given in the January, 1949, issue, page 46.

ANALYSIS: TESTING: LABORATORY METHODS

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Fiber Identification

Identification of textile fibers. N. Willatt. *Can. Text. J.* **66**, 54, 56 (Feb. 18, 1949).

An interpretation of and practical commentary on the Textile Institute's comprehensive handbook entitled "The Identification of Textile Materials." L. A. Fiori

Text. Research J. June 1949

Hair Damage

The detection of hair damage by physical methods. H. Brauckhoff. *Melliand Textilber.* **28**, 181–4 (1947); cf. *C.A.* **40**, 939[4] (through *Chem. Abstr.* **43**, 414*d* (Jan. 10, 1949)).

Measurement of longitudinal swelling is a very sensitive method of detecting damage to hair. The instrument used is a simple hygrometer, modified so that the samples can be readily inserted between the points of suspension. It is first calibrated with an undamaged hair at humidities between saturation and atmosphere. If a damaged hair is then placed in the instrument it will show a greater elongation at a given humidity, the increase in elongation being proportional to the extent of the damage. Data are given showing the superiority of the method, as compared with tensile strength and elasticity measurements, for detecting damage by heat and by acids and alkalies.

Text. Research J. June 1949

Flammability Tests

Flammability of consumer textiles. G. S. Buck, Jr. *Am. Dyestuff Reptr.* **38**, P78–84 (Jan. 24, 1949).

The work reported here was done through the cooperative efforts of the members of the National Bureau of Standards Technical Committee on the proposed Commercial Standard TS-4350 and the Committee on Flammability of Consumer Textiles of the A.A.T.C.C. The A.A.T.C.C. flammability tester and tentative test method and the horizontal flammability tester developed by the Fire Protection Section of the Bureau of Standards have been studied by these committees. They conclude that precise determination of fabric flammability is impossible by either of these testing methods. The inclined flammability tester developed by the A.A.T.C.C. is preferred to the horizontal tester because: (*a*) smaller samples of fabric may be employed, (*b*) operation of the test is simpler, (*c*) results are at least as consistent as those obtained with the horizontal tester, and (*d*) neither method of measuring flammability gives results of sufficient precision to make reference to such tests feasible in any municipal, state, or Federal laws. Certain other specific conclusions and some recommendations are included, as well as an informative report on the extensive work which has been completed. C.A.A.

Text. Research J. June 1949

Fabric Wear Tester

New universal wear tester for textiles. Anon. *Rayon and Synthetic Texts.* **30**, 53–4 (Feb. 1949).

A new textile wear-tester for use in textile research and allied purposes is described. This device produces the 3 major actions of fabric abrasion—flat, edge, and flex abrasion. A brief description of the instrument's operation and a schematic diagram showing its construction are given. L. A. Fiori

Text. Research J. June 1949

New Cotton Strength Test

New cotton strength test. Anon. *Am. Wool and Cotton Reptr.* **6**, 67, 96–8 (Feb. 10, 1949).

It is proposed that the method of testing fabric based upon the use of 1 in. of cloth between the testing jaws be modified to provide more space. It is asserted that the former 1-in. space of fabric will not give true results, particularly with respect to the testing of fabrics made of synthetic fibers.

A. L. Landau

Text. Research J. June 1949

Evenness Tests

Evaluation of evenness tests. Anon. *Textile Inds.* **113**, 92–3 (Jan. 1949).

The planimeter is reported to be used in some mills for the mathematical interpretation of graph-recorded tests in order to eliminate the use of mathematical formulas and laborious calculations. The planimeter is employed by tracing the graph and reading the valuation directly from the instrument in one continuous operation.

A. L. Landau

Text. Research J. June 1949

Speeding Cotton Stapling

Speeding cotton stapling. J. Witherspoon. *Textile Inds.* **113**, 87–90 (Jan. 1949).

An electronic instrument, the Fibrograph, has been developed to speed cotton stapling. Stapling is achieved by projecting a light through the fiber sample and measuring the intensity of the beam passing through the fiber sample and measuring the intensity of the beam passing through the fibers by means of a galvanometer. A graph of length distribution is plotted. The combing of the sample prior to presentation to the machine must be performed carefully to obtain accurate results. Details of the instrument and the method of calibrating it are described.

A. L. Landau

Text. Research J. June 1949

Strobotac Boosts Efficiency

Strobotac boosts efficiency in woolen and synthetic mills. G. Ransom. *Textile Age* **13**, 7, 10, 14, 16, 20 (Feb. 1949).

Strobotac instruments are being used to check the speeds of spindles and other rapidly moving parts of roving, spinning, and twisting frames where it is not convenient to use a tachometer. The Strobotac aids in obtaining maximum efficiency through the adjustment of high speeds checked by visual observation. Methods of using the instrument are outlined and examples are given of tests used in some mills.

A. L. Landau

Text. Research J. June 1949

CHEMICAL and PHYSICAL RESEARCH

★

Fiber Properties and Constitution

The relation between the properties of fibers and their physical and chemical constitution. A. Banderet. *Teintex* **13**, 155–65 (1948) (through *Chem. Abstr.* **42**, 7049*d* (Sept. 20, 1948)).

Discussion of: (1) molecular weights of linen, cotton, viscose, wool, silk, nylon, and polyvinyl chloride; (2) diffraction studies of rayons, linen, and wool; and (3) microscopic studies of transverse sections of Vinyon, Aralac, viscose, and cellulose acetate.

Text. Research J. June 1949

Study of Fibers

X-ray study of vegetable fibers. Bhupati K. Banerjee. *Indian J. Phys.* **21**, 259–66 (1947); cf. C.A. **41**, 4916*c* (through *Chem. Abstr.* **42**, 6541*b* (Sept. 10, 1948)).

This latest of a series of studies of vegetable fibers covers *Pandanus*, *Annanus sativus*, *Sesbania aculeas*, *Hibiscus esculantus*, *Calotropis gigantea*, coma on the seed of *Calotropis gigantea*, *Hibiscus mutabilis*, *Musa sapientum*, *Crotalaria juncea*, *Agave americana*, coir A which had been isolated from green coconut, and coir B which had been isolated from dried coconut. X-ray diffraction patterns were obtained using exposures of about 8 hrs. The results showed that in some fibers the major axis of the unit cell is almost parallel to the fiber axis. In some, the major axis is at some spiral angle to the fiber axis, while in an extreme case the cellulose crystallites are randomly distributed.

Text. Research J. June 1949

Moisture Determination

Moisture determination in textiles by electrical meters: Part II. Richard K. Toner, Carol F. Bowen, and John C. Whitwell. TEXTILE RESEARCH JOURNAL **19**, 1–8 (Jan. 1949). Cf. *ibid.* 526 (Sept. 1948).

This is the second paper in this series reporting experiments on representative moisture meters. It discusses the effect on their calibration of temperature, heating history, wool type and dye, and presents basic types of curves for cotton sliver and acetate staple. All variables affect the calibration sufficiently to require separate curves for each new condition if high precision is to be maintained.

Authors

Text. Research J. June 1949

Elastic Performance of Textiles

Mechanics of elastic performance of textile materials. II: The application of sonic techniques to the investigation of the effects of visco-elastic behavior upon stress-strain relationships in certain high polymers. Walter J. Hamburger. TEXTILE RESEARCH JOURNAL **18**, 705–43 (Dec. 1948). Cf. *ibid.* 102 (Feb. 1948).

A technique is developed for the quantitative evaluation of the deformation components of visco-elastic materials when these are subjected to tensile loading for loads ranging from zero to rupture, under

dynamic loading conditions, at constant rates of load, elongation, or strain for different magnitudes of constant rates of load, elongation, and strain. The technique serves not only to determine the mechanism of elastic performance of materials but also to quantitatively evaluate their performance characteristics as engineering materials. A sensitive and responsive instrument for the determination of the dynamic modulus of elasticity of materials under any and all loading conditions has been developed and is described. Author

Text. Research J. June 1949

Cellulose Chemistry

Cellulose reactions. I. A method for the determination of the distribution of the substituents in the glucose residues of a partly substituted methylcellulose. T. Timell. *Svensk Papperstidn.* **51**, 52–6 (1948) (in English) (through *Chem. Abstr.* **42**, 8466*f*–8467*a* (Nov. 10, 1948)).

The analytical scheme described comprises determination in partly substituted methylcellulose of the number of 2-, 3-, and 6-substituted glucose units, the relative amounts of unsubstituted mono-, di-, and trisubstituted glucose residues, and the number of glycol groups. From these values, the 8 different glucose units are established. The individual methods, previously published but modified by the author, are described in detail. The fraction of the glucose residue substituted in the 6-position was determined after tosylation and conversion to the iodide, the 3-position after degradation to Me glucosides by consumption of periodate after reaction for 96 hrs. at room temperature. The fraction substituted in the 2-position was found by causing the Me glucosides to react with $Pb(OAc)_4$ in AcOH, stopping the oxidation after 1–5 min. in 1-min. intervals, and plotting the moelcules of glycol against time. In view of the fact that the glycol in the 1,2-position causes the initial rapid oxidation, and since the 1-position is always free, the hydroxyl group in the 2-position is derived by extrapolation of the graph. After the methylcellulose was hydrolyzed to monomers, the amount of unsubstituted glucose was determined from CO_2 obtained by fermentation with yeast, the yield being corrected by running a blank with pure glucose. The substituted glucoses remaining after fermentation were converted to the corresponding Me glucosides and were fractionally distilled (*C.A.* **36**, 5781[1]) to give a distillate of tri- and dimethylmethylglucoside and a still residue of di- and monomethylmethylglucoside. Methoxyl values on these 2 fractions allowed the calculation of the percentages of the various mono-, di-, and trimethylglucoses in the methylcellulose. Finally, periodate oxidation of the original methylcellulose established the glycol groups per glucose unit. The procedure is given for the preparation of a methylcellulose with a degree of substitution of 1.18, and analytical results obtained for it by various methods are given. Corresponding data for 4 additional preparations of methylcelluloses with different degrees of substitution will be reported and discussed relative to the mechanism for methylation. 37 references.

Text. Research J. June 1949

Heat of Absorption of Cellulose

The heat of absorption of water by cellulose. W. H. Rees. *J. Text. Inst.* **39**, T351–67 (Nov. 1948).

A method is described for measuring the heat of wetting of textiles at various moisture regains and results are reported for cotton, mercerized cotton, and certain rayons. A review of the literature on the measurement of such heat changes is given. Values of the heat of absorption derived from the heat-of-wetting data are reported. Approximately the same heat-of-absorption value was obtained for all the materials investigated at zero moisture regain—indicating the identical nature of the absorbing matter. The conclusion is drawn that the heat of absorption of cellulose at zero moisture regain is 283 cal. per g. of liquid water. An approximate value of the heat of absorption may be calculated from moisture absorption data by applying a modified form of the Clausius-Clapeyron equation. The thermostatic action of hydroscopic textile materials on the human body is discussed. L. P. Witnauer

Text. Research J. June 1949

Photochemical Degradation

The photochemical degradation of undyed and dyed cellulose irradiated by the mercury spectrum. H. Lanigan. *J. Text. Inst.* **39**, T285–92 (Sept. 1948).

The hypothesis that certain yellow or orange vat dyes accelerate the rate of photochemical degradation of cellulose both by atmospheric oxygen and by other oxidants by sensitizing the cellulose to radiation in the visible spectrum is substantiated by the work described here. A unique method is employed to irradiate the test sample with narrow spectral bands of radiation of known wave length and to measure the amount of photochemical degradation. Test samples of cellulosic fabric exposed in the focal plane of a quartz spectrograph to the full spectrum of a mercury arc are "developed" in an alkaline solution of a complex silver salt, whereupon metallic silver is deposited in the degraded parts of the fabric in amounts proportional to the amount of degradation.

Text. Research J. June 1949 P. J. Fynn

The action of light on viscose rayon, silk, and nylon, undyed and dyed with some vat dyes. G. S. Egerton. *J. Text. Inst.* **39**, T293–304 (Sept. 1948).

A comparison is made of the photochemical degradation of cotton, nylon, rayon, and silk when sensitized by certain yellow and orange dyes. Yarns were exposed in a glass cell under controlled atmosphere to measured quantities of sunlight. Loss in tensile strength, used as a criterion of degradation, showed the effect of active vat dyes

to be greatest on silk, followed, in order, by nylon, cotton, and viscose rayon. P. J. Fynn

Text. Research J. June 1949

The role of hydrogen peroxide in the photochemical degradation of cotton sensitized by vat dyes and some metallic oxides. G. S. Egerton. *J. Text. Inst.* **39**, T305–18 (Sept. 1948).

Evidence is presented to show that during irradiation by sunlight "sensitizing" orange and yellow vat dyes cause tendering of the substrate fibers by the formation of activated oxygen. The activated oxygen acts in two ways—either by immediate reaction with the substrate or by the formation of hydrogen peroxide, which can migrate and attack the fibers at a distance from its place of formation. This is convincingly shown by the fact that undyed yarns close to but not in contact with dyed yarns suffered greater degradation than similar undyed yarns exposed simultaneously with the others but in a chamber isolated from the dyed yarns. Similar tests were made using metallic oxide pigments of zinc and titanium.

Text. Research J. June 1949 P. J. Fynn

Acetylation of Cellulose

Acetylation of cellulose in phosphoric acid solution. E. Heuser, W. Shockley, A. Adams, and E. A. Grunwald. *Ind. Eng. Chem.* **40**, 1500–6 (Aug. 1948).

When fibrous cellulose is esterified the esterification system is heterogeneous owing to the fibrous structure of the material. In order to obtain a more uniform distribution of the acetyl groups over all chain molecules, the cellulose was first dissolved in phosphoric acid and then esterified by means of acetic anhydride. During the dissolving step the cellulose is degraded. Further, but somewhat less, degradation occurs during the acetylation. The degree of degradation is less than with other inorganic acids and varies with the temperature and time. With approximately 100% phosphoric acid and within 30–40 min. at 55°–65°C acetyl contents were obtained which were in many cases only a few percent below that required for the triacetate (44.8%) with a degree of polymerization, calculated from cuprammonium hydroxide viscosities, between 530 and 100, depending upon the degree of polymerization of the original material. The D. P.'s of the original materials varied from 170 to 1,650; of the materials before acetylation, 150 to 960; and of the materials after acetylation, 100 to 530. Triacetate values were obtained within 10 min. when a temperature of 65°–75°C and a large excess of acetic anhydride were used. The possible formation of acetyl phosphates and its probable influence on the acetyl reaction are discussed.

A. R. Macormac

Text. Research J. June 1949

Cellulose-Formaldehyde Reaction

Mechanism of combination of formaldehyde with cellulose. M. Taniguchi and M. Hosono. *J. Soc. Chem. Ind. Japan* **46**, 1105–8 (1943); cf. *C.A.* **35**, 6107[2] (through *Chem. Abstr.* **42**, 6534*c* (Sept. 10, 1948)).

Cellulose treated with paraformaldehyde vapor in a closed vessel at 70–100°C for 2–150 hrs. gave a product containing up to 35% of CH_2O, which corresponded to one CH_2O to each OH group of cellulose. This corresponds to an addition product of CH_2O and cellulose, not to a methylene ether of cellulose.

Text. Research J. June 1949

Mercerization of Cellulose

The mercerization of cellulose by caustic. An interferometric study. E. Calvet. *Compt. rend.* **226**, 1528–30 (1948); cf. *C. A.* **42**, 6123*b* (through *Chem. Abstr.* **42**, 9183*f* (Nov. 20, 1948)).

The change in concentration of a NaOH solution due to absorption by cellulose (*I*) was determined interferometrically. The absorption by mercerized *I* is irreversible at 15°C for 2–5*N* NaOH but becomes reversible at 40°C. For nonmercerized *I*, the absorption is reversible at 15° and 40°C. At 15°C there is a relation between the NaOH fixed by nonmercerized *I* and the caustic concentration; between 2 and 5*N* with nonmercerized *I* there is no relation.

Text. Research J. June 1949

Nitration of Cellulose

Influence of fineness of fibers on nitration reaction. S. Watanabe. *J. Soc. Chem. Ind. Japan* **47**, 723–5 (1944) (through *Chem. Abstr.* **42**, 6534*a* (Sept. 10, 1948)).

A single fiber of ramie 18–30 cm. long was immersed in a mixture of fuming HNO_3 and concentrated H_2SO_4 at 0°C for 1–3 hrs., washed with H_2O, dried, and weighed on a microbalance. From the weight increase, the N percentage was calculated. With the finest fibers the N increased to 14.1% after nitration for 1 hr. and to 14.2% after nitration for 3 hrs. Thicker fibers are nitrated to a lower degree.

Text. Research J. June 1949

Behavior of cellulose in the mixture of sulfuric and nitric acids. S. Watanabe. *J. Soc. Chem. Ind. Japan* **47**, 228–9 (1944) (through *Chem. Abstr.* **42**, 6534*b* (Sept. 10, 1948)).

When cellulose was nitrated in a mixed acid solution low in water content and high in H_2SO_4, the N content of the product decreased rapidly below 18% of HNO_3. It was concluded that H_2SO_4 prevented the contact of mixed acids with cellulose.

Text. Research J. June 1949

Nitration of cellulose. S. Watanabe. *J. Soc. Chem. Ind. Japan* **47**, 226–8 (1944) (through *Chem. Abstr.* **42**, 6534*c* (Sept. 10, 1948)).

The degree of nitration of nitrocellulose decreases rapidly with decreasing concentrations of HNO_3 in the mixed acid solutions. As the nitration proceeds, the surface of cellulose is covered with H_2SO_4, which prevents the nitration reaction.

Text. Research J. June 1949

Reactions of Cellulose Acetate Fibers

The interaction of various organic liquids with cellulose acetate fibers as detected by specific-gravity measurements. Fred Fortess. TEXTILE RESEARCH JOURNAL **19**, 23–35 (Jan. 1949).

The pycnometer liquid displacement method of determining the specific gravity of solids has been applied to the study of the rate and the extent of penetration of a large variety of pure liquids into cellulose acetate yarn. Various members of the homologous series of aromatic and aliphatic alcohols, aldehydes, ketones, ethers, esters, halogens, nitriles, phthalate esters, nitro-compounds, and hydrocarbons were used. The maximum apparent specific gravities obtained for a Celanese yarn were found to be a function of the polar groups on the molecules of the liquid medium, as well as of their size and shape. These values range from 1.306 at 20°C with carbon tetrachloride to 1.415 with *n*-heptaldehyde. A hydrogen-bonding mechanism is suggested to explain the manner by which the liquid-medium molecules penetrate and solvate the yarn. Several applications of this technique and the resultant data are indicated. Author

Text. Research J. June 1949

Cellulose Xanthate

Various problems in the viscose rayon industry. I. Sulfide reaction. S. Matsuhashi and F. Goto. *J. Soc. Chem. Ind. Japan* **47**, 116–19 (1944) (through *Chem. Abstr.* **42**, 7040*a* (Sept. 20, 1948)).

The sulfide degree of cellulose xanthate prepared from commercial pulp for rayon was measured under various industrial conditions. The percentage of combined CS_2 was a maximum when CS_2 was added at 29–30% CS_2/cellulose. **II. The heat of sulfide reaction.** *Ibid.* 119–21.—Alkali cellulose was treated with CS_2 at 20, 25, and 30°C to obtain Na cellulose xanthate. The reaction is exothermic. At a xanthation temperature of 20°–30°C, the maximum heat evolution occurred at 25.5–30% CS_2/cellulose. This corresponds to a maximum of combined CS_2.

Text. Research J. June 1949

Stress-Strain in Viscose Rayon

The stress-strain characteristics of viscose rayons in relation to fibre anisotropy. L. Rose and J. D. Griffiths. *J. Text. Inst.* **39**, P265–96 (July 1948).

Extensive data are presented for 9 series of spun viscose yarns in which the yarns from 6 different coagulating baths were stretched from zero stretch to the breaking point. Conclusions based upon these data are: Birefringence of the unstretched yarn can be explained by the lateral shrinkage of the structure without a corresponding axial shrinkage. The birefringence of stretched yarn, the slope of the (air-dry) load-elongation curve in the elastic region of deformation, and the logarithm of the slope of the (wet) load-elongation curve are all linear functions of stretch relative to the isotropic state. The mechanism of deformation during preparation of the fibers is similar to that for rubber. Deformation in the air-dry state is concerned with hydrogen bond straining and rupture in amorphous regions up to the yield point, and, initially, with hindered chain-uncoiling beyond the yield point. Deformation in the wet state is also initially a chain-uncoiling process. The amorphous regions play a principal part in deformation. If the stretch-spinning of rayon is similar to the stretching of rubber, no increase in crystallization and no change in the free length of the amorphous region occur. Viscose rayon breaks at internal weak spots before the full extension of the structure. L. P. Witnauer

Text. Research J. June 1949

Fibrous Proteins

Surface electrochemical study of fiber proteins. K. Kanamaru and T. Hata. *J. Soc. Chem. Ind. Japan* **47**, 544–9 (1944) (through *Chem. Abstr.* **42**, 6120*f* (Aug. 20, 1948)).

I. Isoelectric point of silk, especially the effect of electrodialysis on it. The isoelectric point of silk in the original state and after 5-, 10-, and 50-hrs.' electrodialysis was determined by measuring streaming potential of silk against dilute HCl and NaOH solutions and plotting the equilibrium ζ-potential against pH. In all the samples, irrespective of the time of dialysis, the isoelectric point was near a pH of 4.15; refined silk after 50-hrs.' dialysis and containing 22.34% sericin showed a pH of 4.10; this agrees with the values for the isoelectric point obtained by some authors of a difficultly soluble component of sericin. **II. Relation between the surface electric conductivity and isoelectric point.** Surface electric conductivity is defined as the relative value of $\kappa_s - \kappa_l$ of equal amounts of samples, where κ_s is the specific conductivity of the surface of the total capillary system and κ_l is the conductivity of the solution alone. Measurements of surface electric conductivity of 4 different samples of silk dialyzed differently with solutions of different pH value showed that there is a minimum of surface conductivity near the isoelectric point. There is another minimum near pure water. With the purification of silk the surface conductivity decreases, but the minimum always lies at the isoelectric point. From the change of surface conductivity with the lapse of time, it was recognized that in concentrated solution ionic adsorption takes place, whereas below a certain concentration of electrolyte (near pure water) desorption of ions, due to impurity, takes place. **III. Isoelectric point of silk fibroin. The effect of the method of removal of sericin and heat treatment on the isoelectric point.** K. Kanamaru, T. Hata, and M. Koike. *J. Soc. Chem. Ind. Japan* **47**, 710–13 (1944). Electrokinetic potential of silk fibroin after removal of sericin in solutions of various pH was measured by the flow-potential method. The pH value corresponding to the isoelectric point is 4.03 after alkali-treatment at room temperature,

4.45 after boiling in water for 24 hrs. at ordinary pressure, 4.57 after boiling at high pressure (130°C) for 3 hrs., and 3.39 after alkali treatment at room temperature and drying at 105°C for 2 hrs. **IV. Hydrogen ion adsorption of silk fibroin.** Hydrogen ion adsorption of silk fibroin in the isoelectric pH range was measured by the glass electrode. The amount of H ion adsorption by silk fibroin free from sericin has a minimum at the isoelectric point, which is due to the minimum capacity factor of the adsorption. Decreasing amounts of H ion were adsorbed on (1) boiling under high pressure, (2) boiling under ordinary pressure, (3) dilute alkali treatment at ordinary temperature and pressure, and (4) drying after treatment as in (3).

Text. Research J. June 1949

Solution of Soybean Protein

Solution of soybean protein. I. Relation of solvent and the shape of the soybean-protein particle. S. Yokoyama. *J. Soc. Chem. Ind. Japan* **46**, 1298–1300 (1943) (through *Chem. Abstr.* **42**, 6616g (Sept. 20, 1948)).

In 0.05*N* NaOH, NaOH-KH_2PO_4 buffer solution of Clark and Lubs (pH = 8.0), NaOH-KCl-H_2BO_3 buffer solution of Clark and Lubs (pH = 10.0), 6.33*M* urea solution, and 8.33*M* urea-acetate buffer solution, respectively, the viscosity and specific gravity of soybean protein of various concentrations were measured, and specific viscosity, axial ratio of solute particle, etc., were calculated. A linear relationship exists between the protein concentration and the specific gravity; the specific viscosity of the solutions containing urea is 3 times as high as that of solutions containing alkali. The axial ratio of solute particle, according to both Polson's and Kaneko's formulas (Polson, *C.A.* **33**, 8084[9]; Kaneko, second following abstract), is greater in the urea-containing system than in the NaOH systems, but the absolute values obtained by the 2 formulas differ greatly. Since Polson's formula comprises an assumption that the protein particle in solution takes 1.59 times as large a volume as does the dry volume, whereas Kaneko's formula requires no such assumption, the value obtained by using the latter formula seems more reliable. **II. Influence of alkali on forms of protein particles.** *Ibid.* **49**, 135 (1946).—The influence of 1% and 1.5% NaOH and 8.33*M* urea solution was studied. These percentages are near those of a soybean-rayon preparation. Density is proportional to concentration; alkali has no effect on density; alkali concentration is reciprocal to η_{sp}. This is an important fact in the rayon and glue industry. NaOH is reciprocal to specific volume when the grain is assumed to be a sphere, and is also reciprocal to the axial ratio in the Polson equation. Urea increases the specific volume and the axial ratio. In this case, Arrhenius' equation becomes inapplicable at a protein concentration of about 1.2%.

Text. Research J. June 1949

Structure and Properties of Polymers

An investigation of the relationship between polymer structure and mechanical properties. Part III: A thermodynamic and optical analysis of the behavior of polyethylene, polyvinyl chloride and lactoprene. R. S. Stein, S. Krimm, and A. V. Tobolsky. TEXTILE RESEARCH JOURNAL **19**, 8–22 (Jan. 1949). *Cf.* **Part I.** R. S. Stein and A. V. Tobolsky, *Ibid.* **18**, 201–23 (Apr. 1948); **Part II.** *Ibid.* 302–14 (May 1948).

Relaxation of stress and birefringence, and stress-temperature behavior of polyethylene, polyvinyl chloride, and lactoprene are examined and interpreted in terms of the molecular processes involved. For polyethylene, it is shown that the reversible and irreversible stress-temperature behavior, as well as the reversible birefringence-temperature characteristics, can be understood in terms of the changes in the character and orientation of the crystalline regions. A thermodynamic analysis of the stress in terms of energy and entropy contributions, both for polyethylene and polyvinyl chloride, serves to substantiate the conclusions drawn from stress and birefringence measurements. The stress-temperature behavior of lactoprene is shown to undergo a marked change in the region of the second-order transition point. On the basis of the stress and birefringence measurements, the increase in stress with decreasing temperature at the second-order transition point can be interpreted in terms of a change in the mechanism of deformation accompanying reversible changes in chain configuration. Authors

Text. Research J. June 1949

Vinyl Polymers

The cross-linking of vinyl polymers by Friedel-Crafts catalysts. I. J. C. Berington and R. G. W. Norrish. *J. Chem. Soc.* **1948**, 771–4 (June 1948).

The production of insoluble cross-linked materials from solutions of various polymers by the action of metallic halides active in Friedel-Crafts reactions is described. Cross-linking occurs by the elimination of a simple molecule, HX, between 2 polymer chains; X may be Cl or $CH_3 \cdot CO_2$. Author

Text. Research J. June 1949

Properties of Starch Solutions

Investigations on the properties of starch solutions. A. Engblom. *Festskr. J. Arvid Hedvall* **1948**, 135–48 (through *Chem. Abstr.* **42**, 8005*b* (Oct. 20, 1948)).

The viscosity properties of potato starch and its behavior upon enzymic and chemical degradation have been studied with respect to its use in the textile industry. The viscosity of starch solutions depends greatly upon the ions present. The great salt-sensitivity of potato starch with respect to the viscosity is specific for this type of starch and can lead to starch molecules with phosphoric acid radicals bound ester-like. The type of water used for the solutions greatly affects their viscosity; 2% solutions in distilled, drinking, and river water gave 148.2,

38.5, and 23.4 centipoises, respectively. The cooking temperature, maximum 95°C, is of practical importance only for very pure starches (low salt concentration). The salts have an equalizing effect on the time-viscosity curve at the boiling point. For the finishing of textile materials with starch paste the most effective and economical treatment is enzymic. Chemical degradation of the starch on cellulose materials is risky. To obtain the same effect as with enzymic finishing, a mineral acid concentration of 0.1 *N* must be used, which attacks the cellulose fiber.

Text. Research J., June 1949

Chlorination of Starch

The chlorination of starch in anhydrous liquid chlorine at 70°. The mono-, di-, and trichlorides of starch. H. N. Barham and T. R. Thomson. *J. Am. Chem. Soc.* **70**, 3321–6 (Oct. 1948).

The chlorination of starch with elementary liquid chlorine has been accomplished. The reaction is kept under control by the use of a sufficient excess of liquid chlorine to reduce the activity of the hydrogen chloride formed, which otherwise leads to a destructive carbonization reaction. The reaction is characterized by a pronounced induction period, an unusual series of color changes in the product, and a reluctance to react beyond the dichloride stage. Both oxidation and substitution occur, and as many as 9 of the 10 hydrogen atoms per glucose unit have been eliminated as hydrogen chloride. Besides forming potentially useful reactive derivatives of starch, the reaction appears to be capable of shedding additional light on the nature and structure of starch. Authors

Text. Research J., June 1949

Color and Constitution

Color and constitution. X. Diazonium salt. H. H. Hodgson. *J. Soc. Dyers and Colourists* **64**, 361–4 (Nov. 1948).

Previous theories relating to the color of certain diazonium salts, in particular the theory of Hantzsch in which, in certain diazonium halides, an equilibrium can exist between the diazonium and diazo forms, such as:

$$Ar—\overset{+}{N}\equiv N\{Hal^{-} \rightleftharpoons Ar—N=N—Cl,$$

wherein the diazo components would account for the color; and the theory of Morgan, who adopted Cain's hypothesis that diazonium salts must be regarded as substances of a hemi-quinonoid character, are reviewed. Both of these theories are found, in general, to be included, with their limitations explained, in the more comprehensive, modern resonant theory of color as developed by Lewis and Calvin, Pauling, Bury, and others. Hodgson finds that Morgan's colorless diazonium salt from *N*-benzoyl-*p*-phenylene diamine and colored diazonium salt from *N*-benzoyl-1:4-napthalene diamine may be readily explained by the resonance theory, whereas the hemi-quinonoid theory is inadequate. The older theory of Hantzsch, Saunder's criticisms thereof, and the viewpoint of Armstrong and Robertson are discussed in relation to the resonance theory. C. Amick

Text. Research J., June 1949

BLEACHING: DYEING: FINISHING

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Direct Dyes

A classification of direct dyes. J. A. Woodruff. *Am. Dyestuff Reptr.* **37**, 691–6, 708 (Oct. 18, 1948).

The data given here are for the use of dyers concerned with the application of dyes to viscose rayon and cotton, and particularly to continuous-filament viscose rayon cakes on spun rayon packages. Approximately 175 direct dyes have been examined to determine their dyeing properties. The dyes have been classified into 4 groups and are listed in tables which give data on their diffusion penetration and exhaustion rates. Methods are described for the application of each class of dyes to viscose rayon cakes. The variables which affect the dyeing properties of direct dyes are discussed. These include "volume ratio," the temperature of the dye bath, the concentration of added salts, and the presence of other direct dyes.

Text. Research J., June 1949 C.A.A.

Decomposition of Direct Dyes

Decomposition of direct dyes during the dyeing of half-wool fabrics. E. Skrutkowski and J. P. Niederhauser. *Teintex* **13**, 313–17 (1948) (through *Chem. Abstr.* **43**, 851*h* (Jan. 25, 1949)).

Boiling for over an hour in a neutral medium causes decomposition of the dye in the presence of free Cl, oxidizing agents, or small amounts of $MgCO_3$ or magnesia. Urea in the dye bath protects the dye against these factors. In an alkaline medium, reducing agents cause decomposition and urea does not protect the dye. Poorly desulfurized viscose badly decomposes the dye and urea gives no protection; 0.5% sodium perborate prevents the decomposition. The amount of urea used represents 8–10% of the weight of the fabrics to be dyed.

Text. Research J., June 1949

Affinity of Naphthol AS

Affinity of naphthol AS group and its effects on dyeing. P. Hassmann. *Textil-Rundschau* **3**, 433–5 (Dec. 1948).

The best affinity of Naphthol AS dyestuffs on vegetable fibers is obtained at about 15°C. The Naphthol AS dyestuffs vary from no affinity to cotton in the case of Naphthol AS-G (yellow) to almost complete extraction of the dye from the dye bath for Naphthol AS-GR (green). The Naphthol AS dyes with high affinity are particularly useful in package dyeing. Uneven dyeing due to variations in density of the packages can be reduced by starting the flow of dye liquor at 70°–80° C, thus decreasing the affinity for a short period until a lower temperature is reached.

Other reasons for uneven dyeing are used-up dye liquor and/or insufficient kiering. High-affinity dyes are also used for dyeing with jigs or reels. For padders, low-affinity Naphthols AS give even dyeing at speeds up to 110 yds./min. Dark shades of good fastness to rubbing can be obtained by repeated dyeing and developing.

Text. Research J. June 1949 J. F. Krasny

Tendering of Cotton Yarn

The effect of sulfur black on the tendering of cotton yarn. Southeastern Section, A.A.T.C.C. *Am. Dyestuff Reptr.* **37**, 833–7 (Dec. 13, 1948).

It seems to be generally recognized that tendering due to sulfur-black dyeing is caused by the development of sulfuric acid. In plant-scale dyeings using sulfur-black, the following appeared to be true: (1) Alkaline after-treatments are effective and practical as a means of decreasing the tendering expected in cotton yarns. (2) An ageing of dyed yarn for 7 hours at 140°C was found necessary to obtain a satisfactory spread in tendering action between original, dyed, and after-treated yarn. (3) Certain chemicals can be used effectively to increase the strength of cotton yarn which has been dyed with sulfur black, such as tetrasodium pyrophosphate, triethanolamine, 0.01*N* sodium hydroxide (0.04% sodium hydroxide), or barium hydroxide. (4) Mercerized yarns resist the action of sulfur-black as a tendering agent. (5) Mercerized yarns under the action of heat tender to a greater extent than do bleached and scoured cottons. C.A.A.

Text. Research J. June 1949

Auxiliary Dyeing Products

Auxiliary products in dyeing. H. C. Borghetty. *Am. Dyestuff Reptr.* **37**, 785–7 (Nov. 29, 1948).

These products are divided into 3 groups—products used in desizing, surface-active agents used in dyeing, and general finishing agents used to modify the physical characteristics of fibers and fabrics. These auxiliary products used in dyeing are classified according to those possessing affinity for the fiber and those possessing affinity for the dyestuff. The author describes some soaps and some synthetics and indicates where they might be used in the textile industry.

Text. Research J. June 1949 C.A.A.

Brine in Dyeing Process

Brine offers savings in dyeing process. Anon. *Textile Inds.* **113**, 106 (Feb. 1949).

Salt brine used as an exhausting agent in dyeing is reported to reduce salt consumption by as much as 12%, eliminate streaks, irregular shades, and spotting, and to save time. A self-filtered brine is made from salt in a special tank. A. L. Landau

Text. Research J. June 1949

Vat Dyeing

Some conditions affecting the application of vat colors. Rhode Island Section A.A.T.C.C. *Am. Dyestuff Reptr.* **38**, P69–75 (Jan. 24, 1949).

Since printing is fundamentally localized dyeing, an examination of the effects of various factors upon dyeing should give indications of how these same factors would affect printing. The variables selected for study included the following: (1) dispersion of pigment particles and particle size, (2) substantivity of the leuco compounds, (3) reduction of the vat colors, (4) solubility of the leuco compounds, and (5) molecular weight. 6 colors satisfactory for printing, 4 colors classified as fair, and 6 colors unsatisfactory for printing were used. It was found that molecular weight had little if any effect upon the printing and dyeing of vat colors. The solubility of the leuco compounds of the vat colors examined was generally satisfactory under proper conditions of chemicals, reducing agents, solvents, and moisture. The ease of reduction of vat colors varies widely from color to color under equal conditions of time, temperature, and chemicals. Temperature affects the rate of reduction and exhaustion in dyeing. In the ageing of prints, temperature determines the relative humidity and moisture absorbed, which, in turn, influences the color yield. With glycerin as a solvent medium, temperature affects the color yield of certain vat dyestuffs. The substantivity of the leuco compounds of the vat colors examined is such that satisfactory exhaustion in dyeing and printing can be obtained throughout the working range of dyestuff concentrations under proper conditions of moisture, alkalinity, and reducing agents. While individual dyes have individual properties, under optimum conditions for each color most vat dyes are suitable for both dyeing and printing. It is not commercially practical at the present time to print certain vat colors because of the effect produced by one or more of the variables studied. C.A.A.

Text. Research J. June 1949

Dyeing Nylon Staple

The effect of fiber physical differences upon the dyeing of nylon staple. R. J. Thomas and B. F. Faris. *Am. Dyestuff Reptr.* **37**, P21–9 (Jan. 12, 1948).

Nylon staple has been found to exhibit greater receptivity for non-penetrating acid and direct dyestuffs than continuous-filament yarn of the same denier per filament. The receptivity for non-penetrating dyes decreases as the denier per filament increases. On the other hand, penetrating dyestuffs exhibit relatively little variation in receptivity between staple and continuous-filament nylon or among nylons of different denier per filament. The wash-fastness of all the acetate, acid, and direct dyestuffs examined, with one exception, is inferior on staple nylon yarns as compared to continuous-filament nylon yarns, but the light-fastness is unaffected by fiber physical variations. However, nylon staple dyed with acid and direct dyestuffs is faster to washing than is continuous-filament nylon dyed with acetate colors. Because of this superiority in wash-fastness, and, in some cases, in light-fastness, the acid colors will be used for the dyeing of nylon staple fabrics in which minor vari-

ations in the affinity of the fiber may be expected to be masked completely. Authors

Text. Research J. June 1949

Hosiery Dyeing

The application of fast colors to mercerized cotton hosiery. C. H. Asbury. *Am. Dyestuff Reptr.* **38**, P58–9, 76 (Jan. 24, 1949).

There is no valid argument for hosiery's being dyed with colors that are not fast, but during the past years hosiery fading has been an accepted fact. The increased use of home washers (washing machines), coupled with the dire results when a sock with poor wash-fastness gets into a white wash, has led to a demand for fast colors on hosiery. Recipes for the application of naphthol and vat dyestuffs to mercerized cotton hosiery are given. C.A.A.

Text. Research J. June 1949

Dyehouse Controls

Remote control of dyeing cycles. F. D. Wallace. *Am. Dyestuff Reptr.* **38**, 92–3 (Jan. 24, 1949).

The problems and procedure of setting up a modern and efficient dyehouse in existing buildings are described. The problem of supplying services, such as lighting, steam and water, and, in particular, of centralized control of the dyeing operation, is discussed. C.A.A.

Text. Research J. June 1949

High-Temperature Dyeing

Some phases of high-temperature dyeing. Philadelphia Section A.A.T.C.C. *Am. Dyestuff Reptr.* **38**, P9–32 (Jan. 10, 1949).

Experimental work on the high-temperature dyeing of cotton, viscose, rayon, cellulose acetate, nylon, and wool is described. Data are presented on the thermal stability of the fibers and dyes, relative exhaustion, relative degree of transfer, relative fastness characteristics, and relative fiber diffusion and penetration. It is concluded that "the increase in speed, leveling, and diffusion found in high-temperature dyeing results in a combination preeminently adaptable to high-speed continuous dyeing with noteworthy gains in fiber quality and economies from volume production. No general statement can be made concerning improvement by high-temperature chroming. Each dye would have to be examined and reported individually, as some show a definite advantage when chromed at 248°F while the chroming of others is definitely impaired."

Text. Research J. June 1949 C.A.A.

Pigment Dyeing

Methods of dyeing with pigments. W. Kirst. *Melliand Textilber.* **28**, 238–40 (1947) (through *Chem. Abstr.* **43**, 411*b* (Jan. 10, 1949)).

The use of printing pigments for the dyeing of cloth is discussed. Various procedures are described and some printing paste formulations are given.

Text. Research J. June 1949

Dyeing and Textile Printing

Advances in dyeing and textile printing processes in England. H. A. Turner. *Am. Dyestuff Reptr.* **37**, 771–2 (Nov. 15, 1948).

Postwar developments in England include improvement in the silk-screen method of textile printing, an increase in the fundamental knowledge of the science of dyeing textiles, and particularly the development of a soluble form of Monastral Blue for application to fabrics. This dye is known as Alcian Blue 8G, can be made to give true dyeings by many of the orthodox methods of application, and, more important, it can be used in printing, alongside, or in admixture with, other classes of dyes. C.A.A.

Text. Research J. June 1949

Printing Techniques

Textile printing techniques. F. S. Richardson. *Am. Dyestuff Reptr.* **37**, P864–5 (Dec. 27, 1948).

Improvement of the Bell roller printing machine, development of photoengraving, photographic printing on textiles, especially for draperies, and offset printing on fabrics to give colored photograph effects are discussed. The Swiss "Orbiss" process of printing is also discussed. This involves building up a print roll of color and gum in a predetermined pattern. When the roll is run against the fabric, the pattern is transferred and the size of the roller is gradually reduced. Dye compositions for this process are patented in the U. S. and a variation of the process is used in England.

Text. Research J. June 1949 C.A.A.

Textile Printing

Textile printing: skill or mystery? E. Broadbent. *Am. Dyestuff Reptr.* **37**, 745–7, 760 (Nov. 15, 1948).

The author mentions several problems which he has encountered in textile printing, and discusses the lack of standardization in the printing industry. He concludes that printing is really a skill, and states that "The printer is constantly under pressure to get production and to keep the machinery constantly operating, and at the same time to cope with all kinds of difficulties to produce perfect goods. The mystery is that he can do so many things and do such excellent work, fitting patterns requiring fine tolerances but using equipment with tolerances so gross." C.A.A.

Text. Research J. June 1949

Dyeing and Finishing

Current developments in dyeing and finishing. L. S. Thompson. *Am. Dyestuff Reptr.* **38**, P6–8, 32 (Jan. 10, 1949). *Cf.* **Changing aspects in dyeing and finishing.** L. S. Thompson. *Ibid.*, P276–80 (Mar. 21, 1949).

A general review of some new methods of dyeing and finishing is presented. Several new ideas discussed in the review are: padding fabrics with enzyme plus a wetting agent to remove starch or size; use of the new pre-setting machine to give a preliminary partial boil-off, eliminate creases, and obtain relaxation; use of synthetic detergents with tetrasodium pyrophosphate in scouring; use of peracetic acid for the bleaching of acetate and or viscose rayon; the development of

direct dyeing cellulose acetate dyes; the introduction of permanent inhibitors to reduce gas fading; the Dytron process for dyeing acetate (solvent method); stabilization of rayon fabrics by the use of urea-formaldehyde and melamine-formaldehyde resins; the glyoxal process known as Sanforset; the caustic alkali process known as the Definized Process; and the use of acetone formaldehyde, which can be termed non-chlorine retentive. New types of machinery are also described. C.A.A.

Text. Research J. June 1949

Piece-Goods Finishing

Modern trends in piece goods preparation, dyeing and finishing. C. N. Rabold. *Am. Dyestuff Reptr.* **38**, P67–8, 77 (Jan. 24, 1949).

The most important trend that has taken place in the piece goods industry over recent years is neither mechanical nor chemical, but it is the wholehearted adoption by the industry of technically trained personnel and scientific operating methods. This has resulted in improved bleaching systems of the rope and open-width types which are very efficient, and in improved washing systems, in which the Williams unit or the Tensitrol washer is used. Dyeing improvements, such as the pad-steam method, or the Williams method, and improved finishing equipment are discussed. Controls and instrumentation to facilitate bleaching, dyeing, and finishing are likewise discussed. Under a section called "future trends" mention is made of: (1) heat reclaimers on bleaching and dyeing ranges, (2) new bleaching processes, (3) a new type of continuous open-width boil-off high-temperature desizing process in which enzymes are used, (4) neutralization with liquid sulfur dioxide or solid carbon dioxide, (5) the behavior of individual dyes in the short-volume high-temperature reduction bath, (6) high-temperature dyeing of vat colors, and (7) a continuous chemical feeding system used in conjunction with an automatic titration system in bleaching and dyeing. C.A.A.

Text. Research J. June 1949

Finishing Synthetics

Latest developments in the dyeing and finishing of synthetic fibers. W. G. Helmus. *Am. Dyestuff Reptr.* **38**, P62–4, 84 (Jan. 24, 1949).

Following a brief consideration of certain pretreatments, such as embossing, singeing, heat-setting (for nylon and glass), scouring is discussed in more detail. The author favors the old-fashioned scouring with a low-titer soap and soft water, but points out that other methods may have their merits. Thorough scouring is a "must" if inferior dyeing is to be avoided. Finishing resins such as urea-formaldehyde, the aldehyde process, Kaurit AF, and acetone formaldehyde are discussed. The replacement of the older finishing oils with cationic and anionic softeners has occurred during the past 10–15 yrs. Improvements in machinery and controls are discussed. C.A.A.

Text. Research J. June 1949

Consumer Complaints

Consumer complaints from new fabrics and finishes. L. G. Johnston. *Am. Dyestuff Reptr.* **38**, P65–6, 76 (Jan. 24, 1949).

The author, a representative of the American Institute of Laundering, points out that during the past year about 3,500 complaint-causing articles have been examined. About $^1/_3$ of these complaints arise from faulty manufacturing of the articles, such as shrinkage, damage from poor sewing, gas-fading, chlorine-retention, and poor color-fastness. Shrinkage is particularly bad for shirts, shirt collars, towels with corded borders or certain novelty weaves. Vat dyes may cause loss in tensile strength, but this problem cannot be assigned to any particular dye. So-called fast colors may lose appreciable strength in laundering owing to mechanical friction, which is necessary in removing soil from garments or other manufactured items. The use in finishing of synthetic resins which retain chlorine, which causes the resin to turn yellow, is a serious problem. C.A.A.

Text. Research J. June 1949

Finishing Symbols

Finishing symbols. C. N. Rabold. *Textile World* **99**, 93–7 (Jan. 1949).

With the aid of a number of interested concerns, *Textile World* has compiled a series of symbols representing various machines used in textile finishing. The symbols are proposed for standardization and adoption throughout the industry as an aid in understanding floor plans of finishing plants.

A. L. Landau

Text. Research J. June 1949

Trends in Fabric Processing

Trends in fabric processing. F. Tripp. *Textile Bull.* **75**, 73–4, 76 (Jan. 1949).

The use of scouring auxiliaries or detergents for scouring before bleaching are discussed. The 3 bleaching compounds used in textile bleaching are hypochlorites, hydrogen peroxide, and textone. The advisability of continuous bleaching is weighed against that for kier bleaching. A. L. Landau

Text. Research J. June 1949

Detergents

Determination of the industrial value of detergents. J. P. Sisley. Translation by P. J. Woods. *Am. Dyestuff Reptr.* **37**, 635–42 (Oct. 4, 1948). Reprinted from *Corps gras, savons*, Jan., 1944.

Methods proposed for the determination of detergent power and studies made by these methods are reviewed. In evaluation for industrial purposes, detergent power is not the only quality which enters into the examination of the properties requisite for various applications. It is necessary to examine these products from the point of view of their action as wetting, foaming, and emulsifying agents, and as dispersing agents in the presence of the salts contained in hard water. Erban's immersion method, Ristenpart's forced immersion method, Herbig's centrifuge method, and the Servo-Schopper method are discussed and compared. Wetting

tests carried out in different textile concerns do not give values which can be used for comparison; it frequently happens that there is a complete lack of agreement between the results obtained in the same establishment. With the Servo-Schopper apparatus it is possible to ascertain precisely the wetting power of the various baths used in textile treatments. C.A.A.

Text. Research J. June 1949

Soaps and Detergents

An evaluation of soaps and synthetic detergents. M. S. Furry, V. I. McLendon, and M. E. Aler. *Am. Dyestuff Reptr.* **37**, 751–9 (Nov. 15, 1948).

This article is from the Bureau of Human Nutrition and Home Economics, Agricultural Research Administration, U. S. Department of Agriculture, and is particularly pointed toward the performance of soaps and synthetic detergents in the home laundering of fabrics. About 16 soaps, 22 anionic detergents, 3 cationic detergents, and 10 non-ionic detergents have been evaluated by measuring the change in light reflectance which they produce on artificially soiled cotton fabrics laundered under standardized conditions. Soaps and synthetic detergents removed more soil at 60°C than at 40°C. In distilled water, soaps removed more soil than synthetics, but in hard water the reverse was generally true. The detergents were analyzed chemically and classified according to the type of active ingredient present. An excellent bibliography is appended.

Text. Research J. June 1949 C.A.A.

Permanent Finishes

Permanent finishes on rayon. L. Shapiro. *Am. Dyestuff Reptr.* **37**, P16–20, P29 (Jan. 12, 1948).

A review of all the important permanent and semipermanent finishing methods for rayon. Included are sizing, softening, and water-repellent treatments, shrinkage-control methods, crush-resistant treatments, and mildewproofing and flameproofing processes.

K. S. Campbell

Text. Research J. June 1949

Synthetic Resin Finishes

Synthetic resin finishes, especially resin emulsions. P. Wengraf. *Textil-Rundschau* **3**, 1–9, 42–7, 79–83 (1948) (through *Chem. Abstr.* **42**, 8519*b* (Nov. 10, 1948)).

A review of U. S. and British patents on synthetic resin finishes, covering vinyls, acrylics, allyls, alkyds, ureas, phenolics, melamines, etc., with special emphasis on resin emulsions.

Text. Research J. June 1949

Sizing Hosiery Yarn

Treating and handling of nylon hosiery to prevent snagging during manufacture. A. J. Olson. *Am. Dyestuff Reptr.* **38**, P60–1 (Jan. 24, 1949).

A satisfactory size for nylon knitting yarn must produce a firm fabric which insulates against snagging, and at the same time adheres to the yarn to such an extent that there is minimum stripping and corrosion of needles. P.V.A. (presumably polyvinyl alcohol), containing a good grade of vegetable oil, has been one of the best. The deficiencies of a polymerized styrene base resin and silica sol are discussed. Special caution must be used in looping and seaming, pre-boarding, dyeing, and finished boarding.

Text. Research J. June 1949 C.A.A.

Preparation and Application of Size

Preparation and application of size. F. D. Herring. *Textile Bull.* **75**, 61–2, 64, 67 (Jan. 1949).

The equipment and procedures to be followed in the preparation of size for slashing are outlined and the components of the size mixture are analyzed. Size ingredients discussed are waxes, gums, penetrants, preservatives, and hygroscopic agents. A. L. Landau

Text. Research J. June 1949

Mercerization of Jute

Influence of temperature and concentration of reacting solution in mercerization of raw jute fiber. N. N. Saha. *Indian J. Phys.* **22**, 141–7 (1948) (through *Chem. Abstr.* **42**, 9183*e* (Nov. 20, 1948)).

Raw jute fibers were treated with NaOH solutions of 5–50% concentration at temperatures from −10° to 60°C and then washed and dried. The products thus obtained were analyzed by studying x-ray diffraction patterns which revealed 3 distinct types: (1) that due to native cellulose, (2) that due to partially mercerized cellulose, and (3) that due to completely mercerized cellulose. The results obtained with jute fiber differed considerably from those obtained by Sisson and Saner (*C. A.* **35**, 4961[2]) with cotton. This was especially true in the 40–50% concentration range at temperatures between −10° and 40°C. An attempt was made to explain the differences.

Text. Research J. June 1949

Moisture Control in Tentered Fabrics

Controlled moisture content of tentered fabrics now a reality. P. M. Platzman. *Textile Inds.* **113**, 149, 151, 153–4 (Feb. 1949).

Precision control of moisture content in tentered fabrics is being maintained by an electronic device which continuously measures moisture regain to within 1% of accuracy. Production has been increased from 25% to 30% at reduced labor costs and steam consumption. The control system consists of an electric hygrometer unit placed near the delivery end of the machine, and a condenser unit over which the fabric passes. Measurement of the moisture content of the cloth is based on the principle that the capacitance of a 2-plate condenser will vary with the amount of moisture contained in the fabric passing between the plates. Since the capacitance of the condenser is greater with a greater amount of moisture, a measurement of the capacitance will allow the moisture content to be determined.

A. L. Landau

Text. Research J. June 1949

Effect of Temperature on Finishing Compounds

The effect of temperatures on finishing compounds. A. H. Noble, Jr. *Am. Dyestuff Reptr.* **38**, P115–21 (Feb. 7, 1949).

The use of finishing compounds usually raises the question of yellowing or odor development during subsequent storage. Four groups of compounds have been studied: (*a*) sulfated oils, (*b*) sulfated tallows and fatty acid softeners, (*c*) synthetic substantive softeners, and (*d*) weighters. Three types of tests were developed: (1) accelerated ageing or drying, (2) rancidity, and (3) scorch. Individual products of these four groups of finishing compounds have different properties. In general, cationic substantive softeners do not have so good a resistance to heat as do the anionic types studied. C.A.A.

Text. Research J. June 1949

Hot-Air Slashing

Hot-air slashing interests Georgia mill men. Anon. *Textile World* **99**, 102, 103, 212, 214, 216 (Jan. 1949).

The Uxbridge hot-air slasher unit is described and its advantages are pointed out. Problems of slashing discussed are wet splitting of the warp, squeeze-roll covering, and leasing. A. L. Landau

Text. Research J. June 1949

Rotproofing

The rot-proofing of textiles and related materials. A survey of literature. M. W. Weatherburn. *Natl. Research Council Can.*, N.R.C. No. **1601**, 184 pp. (1947) (through *Chem. Abstr.* **43**, 413*i* (Jan. 10, 1949)).

Text. Research J. June 1949

Damage in Finishing

Interesting cases of damage in textile finishing and their explanation. II. K. Linsenmeier. *Melliand Textilber.* **28**, 205–7 (1947); cf. *C.A.* **38**, 2501[3] (through *Chem. Abstr.* **43**, 414*d* (Jan. 10, 1949)).

Text. Research J. June 1949

Continuous Bleaching Improved by Instrumentation

Continuous bleaching improved by instrumentation. C. W. Bowden. *Textile World* **99**, 124, 125, 211, 212, 216, 218 (Feb. 1949).

Instrument control of continuous bleaching reduces cost and improves uniformity. Controls maintain speed, measure the flow of steam, indicate steam pressures, control temperatures of solutions, and provide uniform squeeze-roll weighting. A. L. Landau

Text. Research J. June 1949

FIBERS: YARNS: FABRICS: MECHANICAL PROCESSES

★

Cotton Mechanization

Proceedings of the 2nd annual belt-wide cotton mechanization conference (Lubbock, Tex., Oct. 14–16, 1948). Memphis, Tenn., National Cotton Council of America. 29 pages. Free.

This report contains 24 articles on all aspects of cotton mechanization. According to E. D. White, mechanization is necessary in order for American cotton to compete with foreign-grown cotton because farm wages in the U. S. are 12 times as high as in Africa and Asia, and also to meet the challenge of rayon. According to Claude L. Welch, mechanization has made considerable progress since 1947, with research accelerated, mass production of pickers beginning, and a 40% increase in the number of tractors used in cotton-growing states. Dr. J. W. Neeley has listed characteristics needed in cotton for mechanical production and discussed efforts to develop a bractless cotton. According to George W. Pfeiffenberger, mills object to tightly twisted, discolored tufts found frequently in mechanically picked cotton, to the presence of green leaf particles, and to a dull cast in such cotton, but states that these signs are diminishing. Mechanized cotton is said to result in lower grade, higher waste losses, more neps, lower efficiency, but better yarn strength. Other experts discuss mechanization as related to the gin, the farm equipment industry, etc. R. B. Evans

Text. Research J. June 1949

Cotton Spinning Tests

Summary of fiber and spinning test results for cotton varieties grown by selected cotton improvement groups, crop of 1948. Cotton Branch, Production and Marketing Administration, U. S. Department of Agriculture. Washington, Jan., 1949. 27 pages. Free.

The 1948 crop is the third for which the Dept. of Agriculture has published current fiber and spinning test data. Data are grouped for 18 varieties of cotton, to indicate comparisons for the same variety in different growing areas; also for early, midseason, and late harvesting. It was found that the average skein strength of 22s yarn declined consistently from 113 lb. for early-picked cotton to less than 107 lb. for late-harvested cotton. At the same time, picker and card waste increased from 7.7% to 9.4%, and neps per 100 sq. in. of card web from 25 to 31. Beside 14 tables of test results, there is an explanation of test procedures. This report presents all results for the 1948 crop, including results already presented in earlier reports. R. B. Evans

Text. Research J. June 1949

Strength of Cotton Cloth

The strip strength of plain cotton cloth woven from folded yarns. L. F. Pickup. *J. Text. Inst.* **39**, T260–73 (Aug. 1948).

This paper deals with a factor, hitherto unknown, in the design of plain fabrics woven from warps of folded cotton yarns and shows how it can, under certain circumstances, affect the strength of a strip of fabric in the warp direction by as much as 25%. Single-thread tests made on warp threads taken from the cloth show correlative results. The factor, referred to as the "picks-twist ratio," is the ratio of the num-

ber of picks per in. to the folding turns in the length of the warp yarn in 1 in. of cloth. It is expressed by a formula. The types of fabrics covered a range in weight from 5 to 29 oz. per sq. yd., and in weave density from a gauze-like construction of 21 ends and 24 picks per in. of 30/2 to belting ducks with 28 ends of 12/10 and 19½ picks per in. of 7/5. Expressed in ratios of the pre-weaving yarn strength, the strength of the cloth and also the strengths of the threads taken from the cloth are shown to be associated with the picks-twist ratio. It is suggested that the lay of the single yarns in the folded warp yarn is distributed by the driving-in of the pick, and that this is the cause of the lower strength ratio found with certain picks-twist ratios.

Text. Research J. June 1949 L. A. Fiori

Serviceability of Wool Fabrics

Improvement of serviceability of wool fabrics; effect of light and weathering on wool fabrics dyed with various dyestuffs. A. M. Serebrjakow and W. A. Beresina. *Tekstil. Prom.* **1948**, 49 (July 1948) (through *Textil-Praxis* **3**, 404 (Dec. 1948)).

The effect of light and weathering on wool dyed with various classes of dyestuffs is described. Dyestuffs derived from triphenyl methane and acid dyes of the azine type containing penta-valent nitrogen decrease light- and weather-resistance. Azo dyes protect the wool, and acid dyes are better than direct dyes, basic dyes, and indigosoles. Acetic acid in an acid dye bath improves the resistance of the wool; boiling or treatment with sodium chloride decreases it. Treatment with acids and glauber salt does not affect wool; treatment with 16 g./l. tannic acid, and after-treatment with 3 g./l. copper sulfate and 2 g./l. potassium dichromate improves it considerably. Urea formaldehyde, bakelite, acrylic and several kinds of glyptal resins protect the wool; tylose, potato starch, sodium fluoride, boric and salicylic acid showed no effect. Velan PF, Zelan, and zinc chloride destroy wool.

Text. Research J. June 1949

Flame-Resistant Fabrics

The development of flame-resistant fabrics containing wool. A. Johnson. *J. Text. Inst.* **39**, P561–77 (Nov. 1948).

Data are given as proof that charred wool is more flame-resistant than asbestos. The brittle nature of the wool-ash, however, prevents advantage being taken of this feature in 100% wool fabrics. It is evident that increased fire-resistance in fabrics can be obtained by holding large masses of wool in a framework of asbestos, particularly in compound fabric structures in which the outer layers of the cloth are made of asbestos yarns and wadded with wool threads. Conclusion is made that a fabric constructed from wool/asbestos will have 3 times the resistance to flame of a fabric of a similar weight made from asbestos alone. The basic principle involved is to prevent the charred wool from escaping from the interstices of the asbestos warp and filling.

Text. Research J. June 1949 L. A. Fiori

Spinning Calculations

Spinning calculations simplified. Part 5. Anon. *Platts Bull.* **6**, 71–80 (July–Aug. 1948).

Previous charts of this series numbered 1–32 were included in: **Part 1**, *Platts Bull.* **5**, 179–93 (Sept.–Oct. 1947); **Part 2**, *ibid.* **5**, 209–18 (Nov.–Dec. 1947) (cf. *T.R.J.* **18**, 256 (1948)); **Part 3**, *ibid.* **6**, 24–31 (Mar.–Apr. 1948); and **Part 4**, *ibid.* **6**, 49–59 (May–June 1948). In this report are described charts numbered 33–9. Information on: distribution of drafts between 4-roller, ordinary-draft ribbon-lap and drawing machines and 5-roller high-draft drawing frames; draft gears on the drawing frame for determining various constants and total drafts; drawing frame productions for various front-roller diameters and speeds; and conversion of hanks into pounds, and grains into hanks.

Text. Research J. June 1949 L. A. Fiori

Spinning calculations simplified. Part 6. Anon. *Platts Bull.* **6**, 112–18 (Nov.–Dec. 1948).

This report contains charts 40–44. Obtainable from these graphs are: draft change gears required for a given total draft on the 3-line and graduated-draft speed frames; and the distribution of the draft between the rollers on a 3-line speed frame, 4-line graduated-draft speed frame, 2-zone high-draft speed frame, and 2-zone Casablanca-type high-draft speed frame. L. A. Fiori

Text. Research J. June 1949

New Saco-Lowell System for Processing Worsted Yarn

New Saco-Lowell system for processing worsted yarn. J. L. Beacon. *Textile Age* **13**, 78–80, 82 (Feb. 1949).

The use of ball packages eliminates the need for roving cans in the new system for spinning worsted yarn. The roving frame is fed by balls in the creel. The system features a new roving drafting system, a vertical ring on the spinning frame, and the Z drafting system for drafting at the spinning process.

A. L. Landau

Text. Research J. June 1949

"American" System

Spinning cotton, rayon and wool on the "American System." R. M. McConnell. *Whitin Review* **15**, 10–23 (Nov. 1948).

Details of the "American System" of producing worsted and blend yarns are presented. L. A. Fiori

Text. Research J. June 1949

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